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# Canadian Aeronautical Journal



CONTENTS



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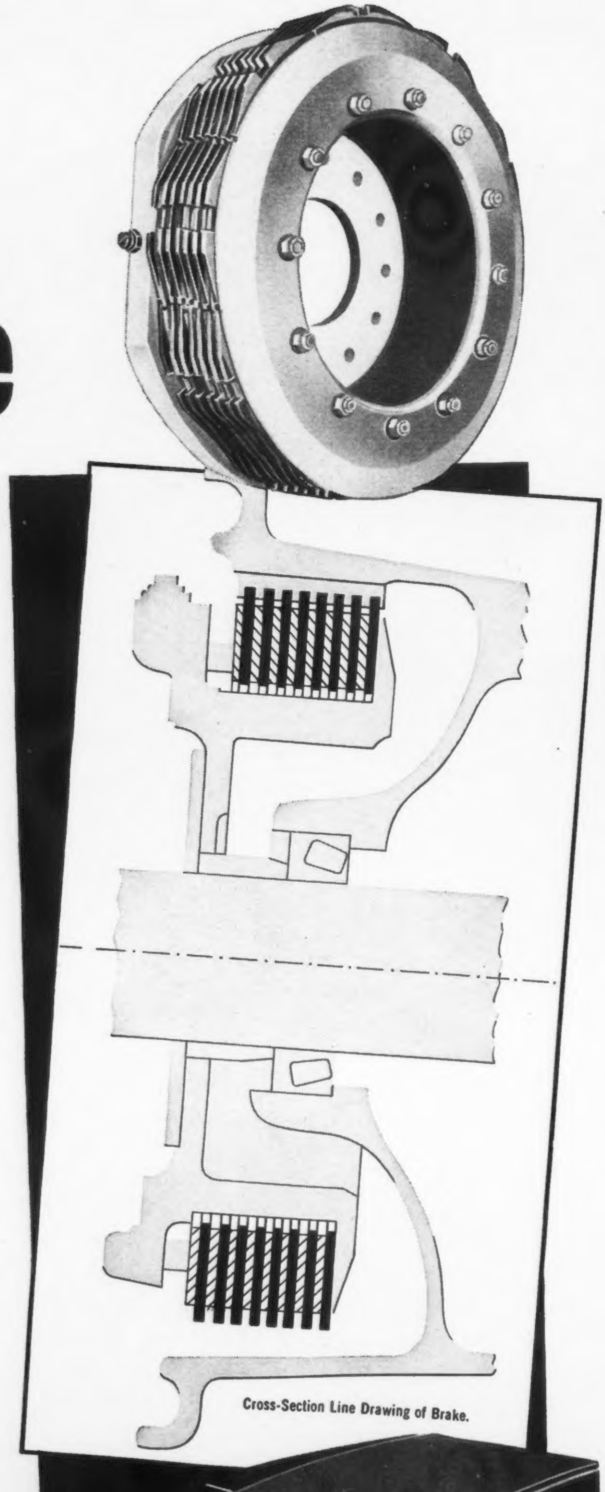
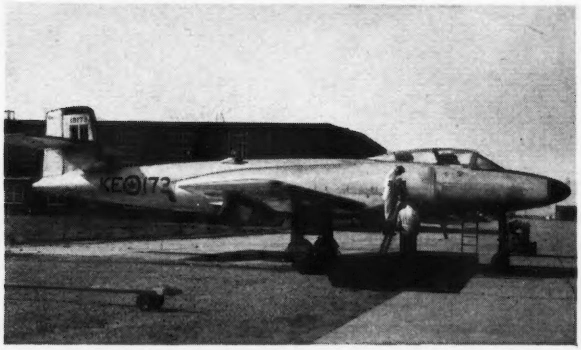
U.S. ARMY

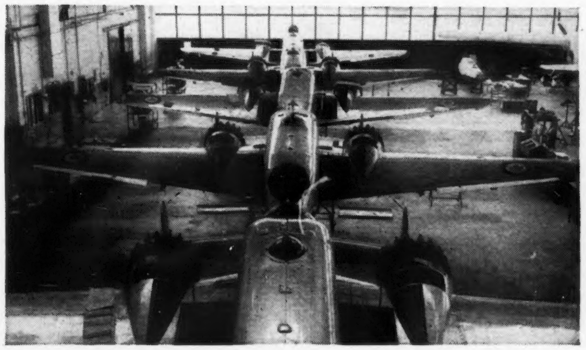


Cross-Section Line Drawing of Brake.

Typical Disc Cross-Section Through Friction Drive.




The Company undertakes considerable modification work for the RCAF, including the conversion of CF-100 interceptors to 2-seater trainers. Components for the Navy's CS2F-1 are also being manufactured in this plant.



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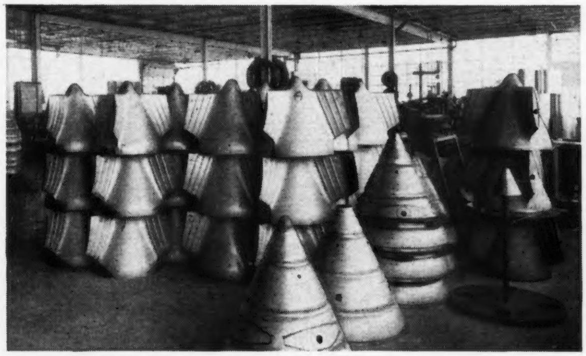

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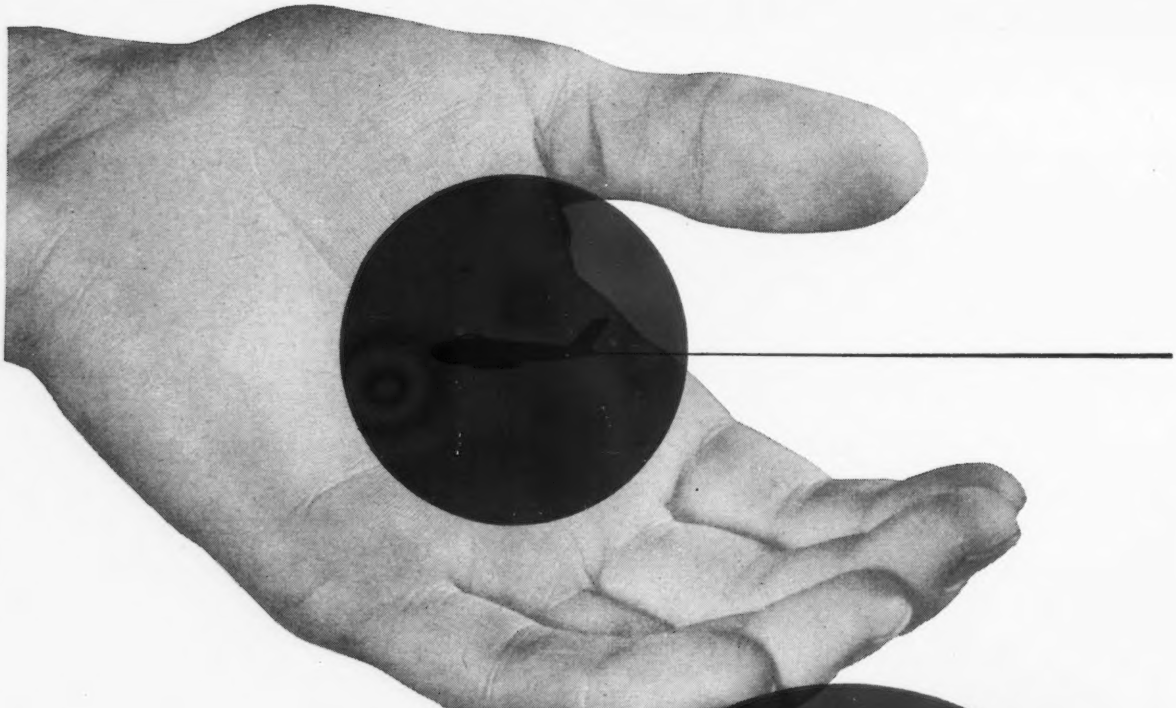



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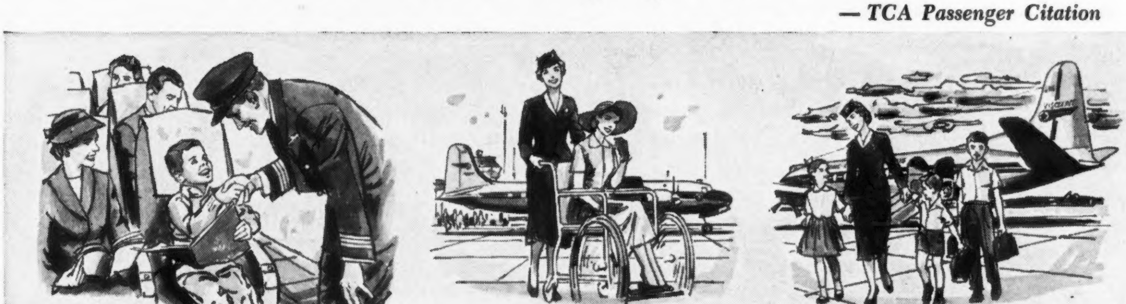

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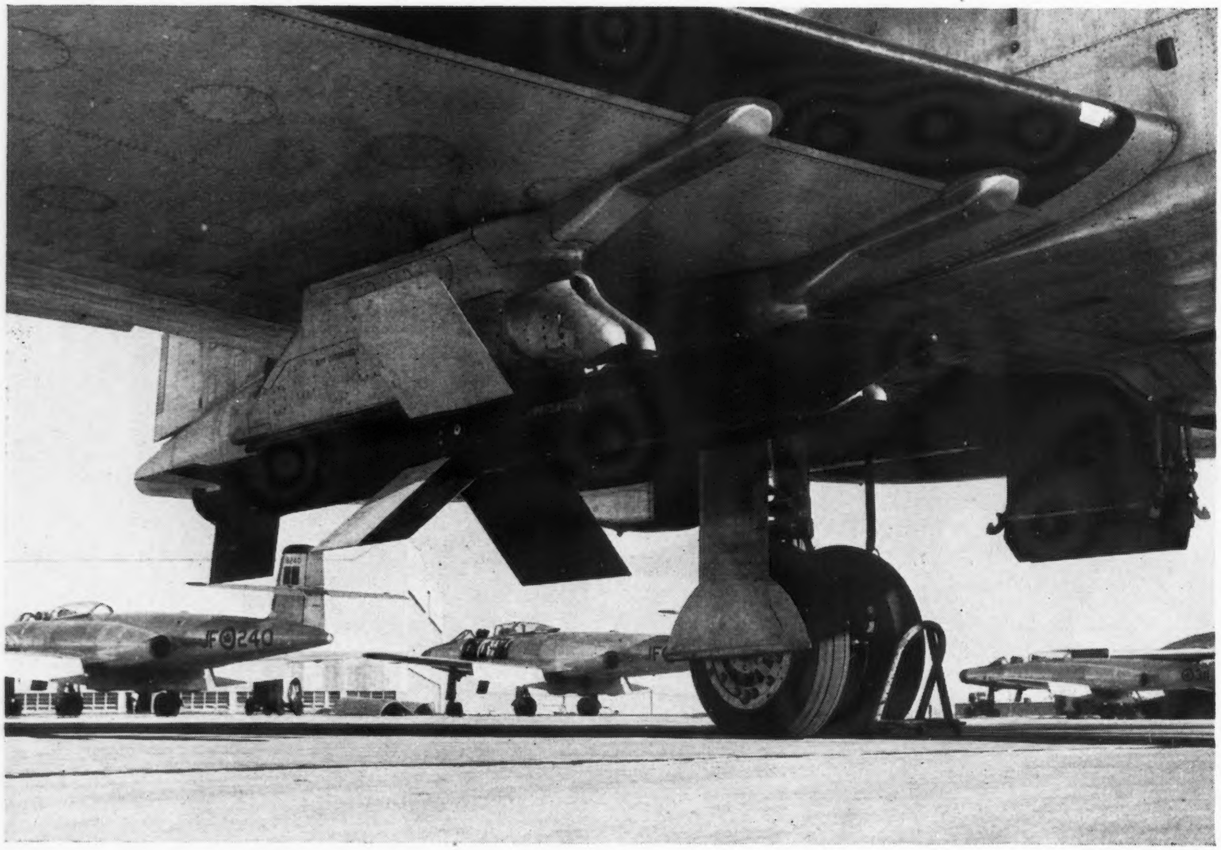
# VELVET GLOVE




**A Velvet Glove air-to-air guided missile slung under the starboard wing of a CF-100 aircraft.**

# EDITORIAL

## A MESSAGE FROM THE I.A.S.

YOUR Secretary's invitation to write (for the third time) a "message" to appear in the issue of the Canadian Aeronautical Journal immediately preceding the joint C.A.I.-I.A.S. Meeting, left us a bit "stumped", if we may resort to an old Yankee expression. Congratulations on birth and survival of infancy of the C.A.I. would be overdue – and have already been done. Nor has the organization yet attained an age where mere longevity is in itself a fit subject for comment. (Fifty years from now the job will be easier – but someone else will have to worry about that!)

What can be said about an organization which has achieved a position of respect and stability and is rolling along, doing its day-to-day job of serving its "customers" well? Perhaps that in itself is enough. To have accomplished that much in three years' time is a great credit to those who organized and saw it through the first difficult years.

We do not have the records at hand, but from where we sit it is apparent that much real progress has been made. Compared with other efforts of a similar nature, the rate of growth of the C.A.I. has been astonishing. Clearly there was a real need which has been well filled by the new organization. Membership has grown rapidly and, best of all, it seems to be an active membership. Interest in participation in meetings and in Branch activity seems high and the quality of the papers that have been presented has been excellent. The establishment of the W. Rupert Turnbull Lecture is noteworthy.

Congratulations are in order for the job that has been done by the JOURNAL. We are very much aware that publications of this caliber do not spring full-blown from anywhere. They are the product of hard and conscientious effort by many people – contributors, editors and printers. We vote full marks to those responsible.

In arranging the details of this third joint meeting, we found few difficulties or complications. We were dealing with a going concern within the framework of well-established experience in such matters. A basis of common understanding has been developed between our working groups that makes such exercises simple and easy. Our two Secretaries, Charles Luttman and Bob Dexter, work together as a team, almost as for a common organization.

We feel that the word "international" scarcely applies to our operations. Our interests in advancing the aeronautical sciences are common. Many of our activities are joint. We feel at home and at ease wherever we meet – in New York, in Toronto or in Buffalo, in Ottawa or in Montreal. This is strictly as it should be.

We are looking forward to the Toronto meeting. It will be a reunion of Old Friends and Ancient Collaborators. This, again, is as it should be.

We look forward to many more such meetings as the years roll on.

S. PAUL JOHNSTON,
*Director,*
*Institute of the Aeronautical Sciences*

# OPERATIONS RESEARCH AND THE CANADIAN AIRCRAFT INDUSTRY†

**by Dr. W. R. Hossack***

***Avro Aircraft Limited***

**OPERATIONS RESEARCH**

OPERATIONS research is scientific research into the problems confronting executives of organizations. The researcher endeavours to analyze a problem in an objective manner, weigh the objectives involved and finally arrive at an optimum solution to the problem.

The reliable operations research scientist must be capable of two things. Firstly, he must be able to perform with agility the numerous mathematical tricks and methods which are employed in modern analysis. Secondly, and equally important, he must be a first class logician. Imagination and confidence are also most desirable in the operations research worker.

**OPERATIONS RESEARCH APPLIED TO THE INTERCEPTOR WEAPONS SYSTEM**

The methods of operations research can be best illustrated by the use of an example. Let us consider the operations of an interceptor aircraft weapons system. Presumably, the objective of such a weapons system is to inflict as high a kill as possible upon the enemy for a given dollar investment. This dollar will be invested in the many components of the interceptor system. A certain proportion will be devoted to the aircraft itself in order to achieve good fighter performance. A certain proportion will be spent on achieving good maintenance and serviceability. Similarly, a certain proportion will be spent on the electronic system in the aircraft, on the interceptor's weapon and so on. There will be a best way to spend the dollar. For instance, if too much is devoted to performance and not enough to serviceability, we may end up with a fine aircraft which is never available for use. This, of course, is not optimum. Operations research is employed in this problem to optimize this partitioning of the dollar.

For a beginning, the operations research worker draws up a chart similar to the chart shown in Figure 1. This serves to sketch out the relationship of the individual components of the interceptor weapons system to the overall probability of kill. Reasonable assumptions must be made concerning attack philosophies. If more than one attack philosophy is employed in the analysis, weights must be assigned to the different philosophies and the optimum partitioning of the dollar made accordingly.

†Received 10th July, 1956. Opinions advanced in this paper are not necessarily those of Avro Aircraft Ltd.

*Senior Engineer, Weapons Systems.

In making the analysis, the research worker varies the relative investments in various components of the system, keeping uppermost the increment in overall probability of kill obtained per dollar invested in any component of the system. In doing this, he defines the optimum solution as the solution in which the distribution of expenditure amongst the various components of the system will be such that an incremental dollar invested will be equally rewarding regardless of the component in which it is invested. This is the method of marginal utility and will give the system with the highest probability of kill for a fixed expenditure. It should be noted, however, that in practice, improvements to many components of the system are often step functions of the variables. In this event, the method, which assumes continuous variables, must be suitably modified. Also, in many cases, the method must be extended to include varying development times etc. Because many of the components are inter-related and must be varied simultaneously, the use of a digital computer with the facility to vary and optimize many parameters at once is most desirable.

Although this operations research necessarily involves assumptions and weighting, the results are usually far from trivial and the scientific result helps the executives concerned to make reasonable decisions and to assess the value of their intuitive hunches in an objective manner. This does not mean that operations research interferes with the process of arriving at executive decisions. Its main objective is to provide additional reliable and integrated data upon which such decisions can be based.

**TWO TYPES OF OPERATIONS RESEARCH**

The interceptor weapons system is an example of military operations research. The general category of military operations research covers all research into operations having to do with warfare. Military operations research was not officially used until World War II when it achieved great prominence – particularly in the fields of air and submarine warfare. Since 1945, non-military or industrial operations research has been playing a greater and greater part in business and industry. The larger companies in Great Britain and the U.S.A., and to a lesser extent in Canada, are today finding it worth their while to have operations research teams integrated into their organizations. The industrial operations research worker employs the same sort of analysis as does the

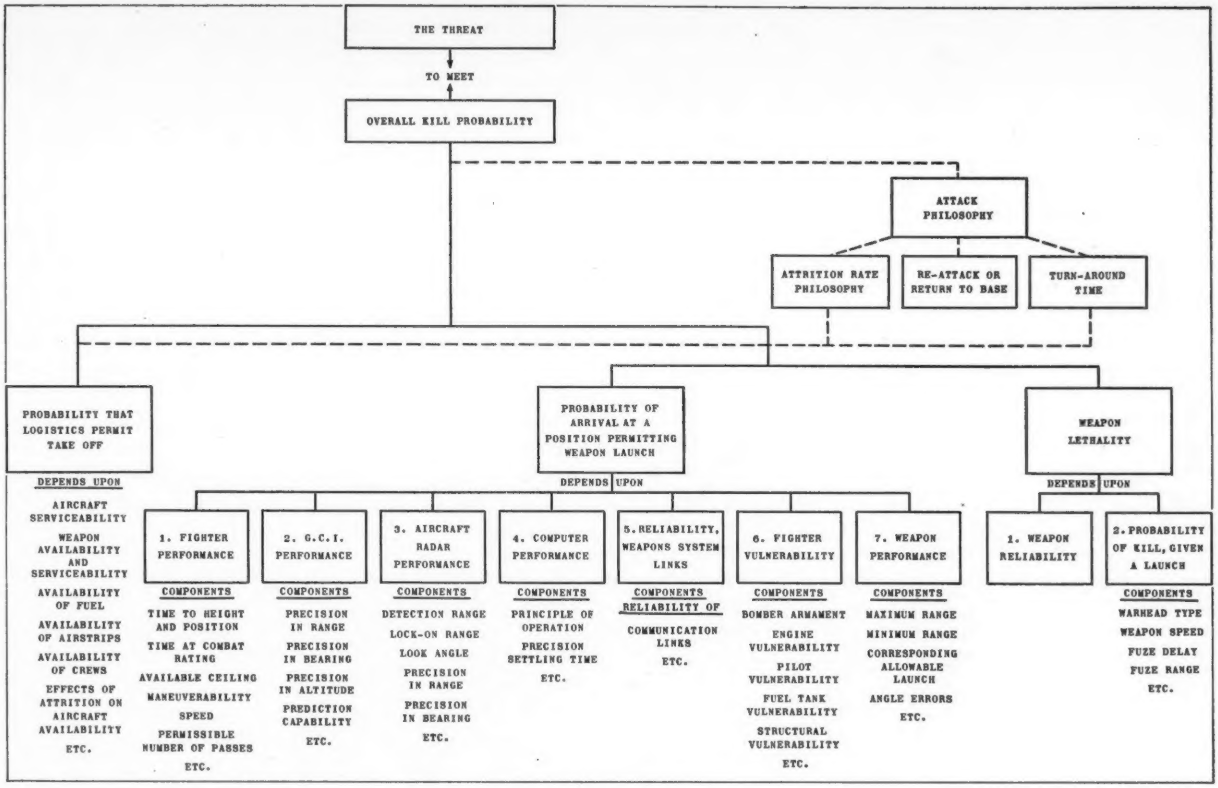



**Figure 1**
**The relationship of the individual components of the interceptor weapons system to the overall probability of kill.**

military operations research worker. Of course, he applies this analysis to industrial problems instead of military ones.

The Canadian aircraft industry has an interest in both military operations research and industrial operations research. Let us first consider military operations research.

### MILITARY OPERATIONS RESEARCH AND THE CANADIAN AIRCRAFT INDUSTRY

The role of operations research in the interceptor weapons system has already been sketched out. A similar systems optimization could be carried out for an anti-submarine aircraft. In this case, the objectives would probably be multiple – such as killing the submarine, denying the submarine the use of the surface, or simply localizing the submarine for kill by some other agent in the overall weapons system etc. These separate objectives would have to be weighted before optimizing the anti-submarine aircraft weapons system. Components in the system would be similar to the components in the interceptor system, such as aircraft performance and range, radar, weapon etc.

It should be noted that, where a Canadian government development contract is concerned, much of the operations research is often carried out to determine the service requirements before any contract is let out to industry.

The Canadian aircraft industry is at present entering the era of the guided missile. A guided missile is a complicated weapons system indeed and is a most rewarding subject for operations research studies.

In a guided missile system, the components are largely inter-related and scientific analysis of the system becomes both very necessary and very complex. For instance, the airframe dictates the environmental conditions, size and weight limitations etc., for the missile-borne guidance equipment and warhead – acting at the same time as an element in the guidance system with predictable transfer characteristics. The contrasting needs between the design of the airframe as a structure and as an element in the guidance system must be compromised, and an optimum design arrived at. Similar considerations apply to other components of the missile system and the finding of the optimum overall system requires a great deal of intricate analysis.

There are many other applications of military operations research to the aircraft industry. The determination of the best principle to use for an interceptor fire control computer is in itself very complicated and requires a careful study of tactics – in many cases long before the aircraft is in the air. Warhead lethality studies are also intricate studies in themselves. Let us, however, pass along to industrial operations research.

### INDUSTRIAL OPERATIONS RESEARCH AND THE CANADIAN AIRCRAFT INDUSTRY

Industrial operations research covers a broad field of application. It may be applied to various problems in production scheduling. One such problem is the parts-

inventory problem. The minimum parts-inventory necessary to maintain a current level of shipments is not always the best one. The size of the inventory can often be varied to reduce production costs with direct results in operating profits. Operations research can set up production scheduling models and, after the application of mathematical techniques, arrive at the optimum schedule. Involved in the research would be the effects of production scheduling on costs of raw materials (since they might be bought and hauled in larger quantities), the costs of storage facilities, possible shortages of particular parts etc.

Maintenance and servicing problems can often be solved using operations research. Each breakdown of aircraft equipment can be remedied as it occurs, either by repair or replacement of the faulty unit. There will be a certain cost associated with each breakdown, not the least part of which will be associated with loss of time on the aircraft. The possible occurrence of these breakdowns in flight may also affect the overall safety factor. On the other hand, preventative maintenance up to a point can sizeably reduce these breakdowns. By weighting the above factors, research into the maintenance operation might establish the optimum procedure. Statistical research into the history of past breakdowns may contribute a great deal to the solving of the larger operational problem, by indicating where and when (in terms of hours flown) breakdowns are liable to occur. It should, of course, be noted that in the aircraft industry the importance of the safety factor usually merits the use of maintenance at almost any cost, providing it buys a fair bit of safety factor. Thus, the optimum solution here is the solution which maximizes the safety factor rather than simply minimizing cost. This points up the fact that operations research is not dealing with an optimum as a scientific abstraction, but as a practical measure of the desired result.

The technique of linear programming has been employed by Charnes et al[1] in connection with the blending of aviation gasolines. Linear programming refers to methods of solving a general class of optimization problems dealing with the interaction of many variables subject to certain restraining conditions. In this particular problem, specifications and prices of selected grades of commercial aviation gasoline are given in terms of minimal octane ratings, maximal vapour pressures and maximum permitted concentrations of tetra-ethyl lead. Prices and chemical properties relative to output ratings are also given, as well as upper limits on the capacities of input materials which can be used to produce the various grades of gasoline. The problem is to combine the inputs in the production of the outputs in such a way that maximum receipts will be obtained, at the same time avoiding the need for additional storage capacity.

There are unlimited possible applications of operations research to the industry which could be cited. However, there is one important problem, not yet mentioned, which is uniquely Canadian in its environment. This problem concerns the long range forecasting of the market for aircraft. For instance, the gradual transfer of population to centers in the north is opening up a new field for transport aircraft. Forecasts must be made today for the transport which in 1970 may be at the height of its operation. Although an aircraft on the design board today would be operational in, say, 1962, it could still be operational as late as 1975. (The DC-3, for example, is still chugging along after twenty years of service.) Operations research into this general problem would involve statistical surveys of Canadian population and economic trends. Forecasts concerning the state of possible alternatives to air transport, such as railways, motor transport etc., would also have to be included in the overall problem. The possibilities of helicopters for urban and inter-urban use might also present a most rewarding operations research study.

## THE PROPER SET-UP FOR AN OPERATIONS RESEARCH GROUP

The proper set-up for an operations research group is of interest to any organizations wishing to initiate this type of research. The work of an operations research section is initially dependent on the accessibility of data from all sections of the company, and strong support at the top level is essential. The Operations Research Group of the Case Institute of Technology conclude[2] that it does not make a great deal of difference where the Operations Research Group is located within the company structure, providing it reports to an executive who is in the first place interested in the possibility of operations research activities and, secondly, able to take action on the findings of the group in relation to any problem.

## CONCLUSION

Operations research appears to have much to offer to aircraft firms. By virtue of the fact that its methodology is equally applicable to commercial or military aircraft, operations research is probably destined to hold a permanent place in the Canadian aircraft industry.

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(1) Charnes, A., Cooper, W. W., Mellon, B. — *Blending Aviation Gasolines — A Study in Programming Interdependent Activities,* Project SCOOP, Symposium on Linear Inequalities and Programming, USAF HQ, Washington, 1952.

(2) Operations Research Group, Case Institute of Technology — *Introduction to Operations Research,* in press, John Wiley and Sons Inc., for release in late 1956.

# WORLD GLIDING CHAMPIONSHIPS — 1956†

**by J. W. Ames***

***Avro Aircraft Ltd.***

SUMMARY

A brief report is presented to the C.A.I. and through this organization to the Canadian industry and others who assisted the Soaring Association of Canada to send a team to the World Gliding Championships at St. Yan, France. Mention is made of some of the equipment and pilots presented by twenty-five nations that participated and particular attention is paid to the equipment and efforts of the Canadian team. Recommendations are included concerning practice for future contests.

**INTRODUCTION**

To most of the participants in gliding activities, whether or not they are associated with pre-military training, gliding is either a pure sport or an engrossing engineering exercise. As a sport it can be ranked with the best. It requires a skill that can be learned and improved throughout a lifetime; it requires team work and good fellowship to become airborne and, once there, is entirely dependent on the individual at the controls; it is competitive in many ways—in competition with nature, with the performance of other pilots at other times and, in direct races, with other pilots under the same conditions. Finally there is a selective element of risk to give it exhilaration. As an engineering exercise, it requires the only advanced form of flying machine which can be conceived and designed in detail by one man in a reasonable time. Manufacture may, of course, be well beyond the purse of individuals and even clubs.

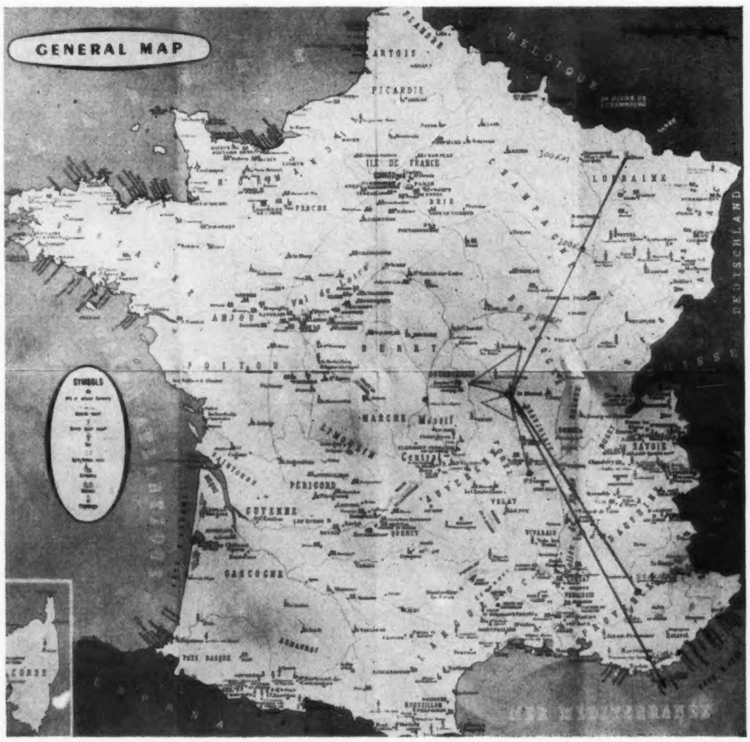


**Figure 1**
**France and the location of St. Yan**

The records and international competitions are controlled by the Fédération Aéronautique Internationale, the same governing body that registers the powered flight records such as the current British achievement with the Fairey Delta. Each country has its national aero club controlling its sporting aviation. In Canada, this duty falls to the Royal Canadian Flying Clubs Association which in turn delegates all gliding matters to the Soaring Association of Canada.

The Soaring Association of Canada selects and presents a team for the World Gliding Championships. Funds are obtained by appealing to the aircraft industry and other interested firms, by contributions from some of the gliding clubs and by expenses paid on their own behalf by members of the team. About $4,500 was required in 1956. The SAC sincerely believes that gliding, and particularly national and international competitions, can have a decided effect on the basic airmindedness of Canada and that this alone justifies the support of the aircraft industry and the RCAF. The Soaring Association is greatly indebted to the industry and to other subscribers, who contributed $3,230, and to the Air Force for the loan of retrieving trucks and drivers throughout the period of the recent competitions.

†Paper read before the Toronto Branch of the C.A.I. on the 12th September, 1956.

*Chief Test Engineer (Structural & Mechanical)

After some changes, due to various reasons including a skiing accident and our inability to borrow a two seater glider of adequate performance, it may now be recorded that the Canadian team at the 1956 World Gliding Championships consisted of Frank Brame and the writer as pilots, Frank Woodward as Team Captain, Gordon Oates and Eric Best as Crew Chiefs, and Chris Falconer, George Stanley, Lawrence Landry, Dr. Sheila Aldersmith (of England), and F/L Benjamin and RCAF drivers, J. F. McLeod and Andrew Larue, of the Canadian Forces in France.

**SETTING THE STAGE**

The Championships are held every two years and, in general, take place in the country of the previous winner. Time, distance and expense may make this impossible in 1958, since the winner of the 1956 contest was Paul B. MacReady of the United States.

St. Yan, France, was chosen for the 1956 competitions. It lies about two hundred miles south and a little east of Paris and is at the north end of a broad plain by the Loire river (Figure 1). In early July it normally provides good soaring conditions on west and south-west winds with best distances being obtained in flights to the German and Luxembourg borders just beyond Metz. This year it produced a magnificent display of diverse meteorology with weak thermal soaring, small active cumulus clouds, mighty cumulo-nimbus, turbulent ridge soaring near the wooded and rocky slopes of the foothills of the Alps, and high altitude wave soaring to the Mediterranean coast. Winds were varied, but frequently blew from the north and north-west.

St. Yan is one of the six civilian schools for powered and gliding flight training, as well as for the training of parachutists, and is specifically used as an aerobatic school. Aerobatics, which would put most Canadian displays to shame, were frequent to the point of boredom. M. Agesilas, the director of the six schools, was executive head of the large staff that was needed for the contest. Included were meteorologists, instructors, towpilots, starters, observers, scorekeepers, interpreters and many others. In general it was a well organized, excellently run international meeting, in which the French should take just pride.

The contest opened on June 29th with the impressive ceremonies normally associated with the Olympics. The flags of twenty-five nations were raised, national anthems played, teams presented, and some sixty of the world's best sailplanes displayed. The Canadian team, Figure 2, is shown standing by their flag pole.

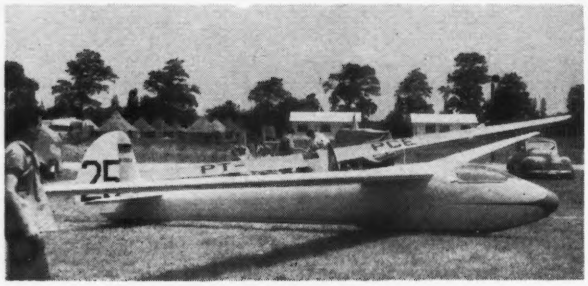

**Figure 3**
**Geier II**

**EQUIPMENT**

Frank Brame flew the Geier II, Figure 3, a new sailplane of German manufacture loaned to Canada by its designer. It was of wood construction with a narrow, rather plain fuselage and elegant, high aspect ratio (23:1), shoulder position, laminar flow wings. The prototype had rather small ailerons and minor cockpit annoyances, but was nonetheless an excellent sailplane and certainly in the performance bracket required at a world competition.

The author flew the Bréguet 901S, Figure 4, loaned by France. The French Air Ministry has ordered sixty of these sailplanes for use at contests and for specific flying assignments. The rumoured unit price is $12,000. It is a sailplane of conventional high performance design, particularly well equipped with expensive but desirable refinements. The span is 57 ft and the aspect ratio 20:1. The wing is a NACA 63 series laminar section with powerful spoilers, divebrakes and Fowler flaps. The undercarriage is retractable by a hand lever motion and is equipped with hydraulic wheel brake. Water ballast, to improve performance on high strength soaring days, is carried in rubber sausage shaped tanks in each wing and can be jettisoned in three or four minutes. The fuselage is smaller than comfort demands, but is of

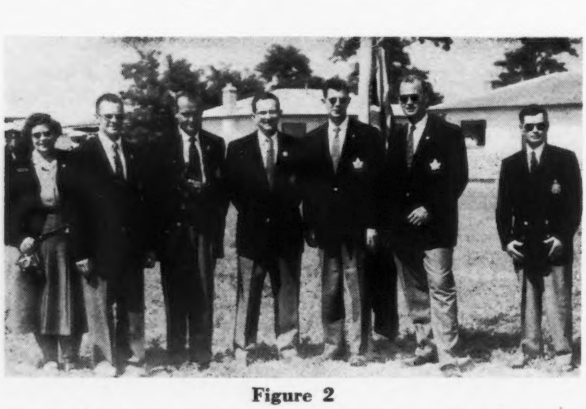

**Figure 2**
**Canadian team (l to r) Dr. Aldersmith, Ames, Brame, Woodward, Oates, Best, Benjamin**

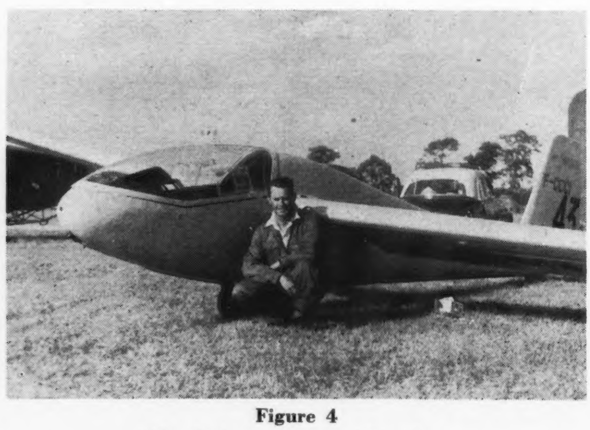

**Figure 4**
**The Bréguet 901S and author**

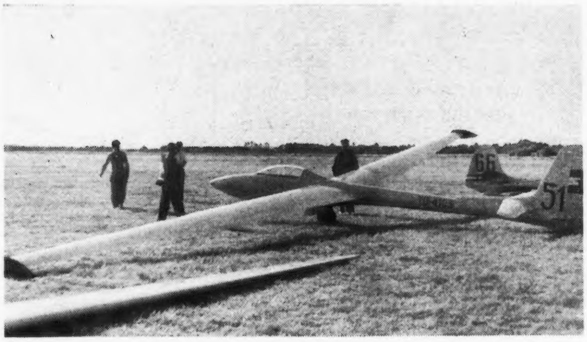



**Figure 5**
**Yugoslavian Meteor**

aesthetic airfoil shape and provides excellent low drag characteristics with good visibility.

A great deal has been written in many languages concerning the sailplanes at St. Yan. A longer article than this would be necessary to do justice to a technical description of only a few of the more sophisticated designs. Yugoslavia had perhaps the epitome of current development in the all metal Meteor, Figure 5. Czechoslovakia's Demant and Switzerland's Elfe were excellent examples of the art, and Germany's HKS series with their unblemished wings, having rolling control by tip section camber changing, were worthy of special note. The Zugvogel, Figure 6, flown by Hanna Reitsch of Germany, although of less complex design, gave excellent performance. With the sophisticates were the many simpler designs, such as the Sky and Skylark 3 from England. Designs such as these are still the principal steeds of world competitors and serve to demonstrate that it is the pilots who win. Reference 1 covers the technical aspects in considerable detail.

The two seater contest was run at the same time and with the same events as the single seaters, although scoring was separated. The FAI intends that this shall be the last such contest. In future, the two seaters will compete with the single seaters with the winning first pilot being named World Champion. On this occasion, Nick Goodhart and Frank Foster of England flying a Slingsby Eagle, Figure 7, demonstrated outstanding ability and won the two seater contest as decisively as Paul MacReady won the single.

**PRACTICE WEEK**

A week of practice is allowed for in contest planning. Towing is laid on for certain periods each day, meteoro-

**Figure 6**
**German Zugvogel**

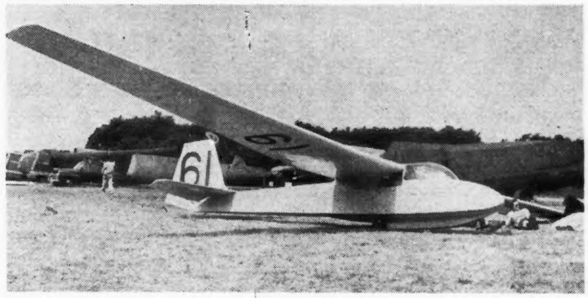



**Figure 7**
**Slingsby Eagle**

logical briefings are given and triangular courses that may be used in the contest are specified. On the final day, a full take-off of all sixty machines was arranged. With some twenty Stampe towplanes at work, all sailplanes were airborne in thirty-five minutes. Several national records were established or broken during this period. Canadian records were set when, on the same day, the author was able to claim a trip around the 200 km triangle in just under five hours and Frank Brame completed the 100 km triangle.

**THE CONTEST**

Friday, June 30th, the first flying day of the contest, provided a rather complicated meteorological situation and soaring conditions much like those found in Ontario. The Committee declared a free distance day and Frank Brame named the airport at Metz as a goal. He made the 207 miles without too much difficulty after some unpleasantly low altitude at about the 60 mile mark. This was a new Canadian goal record and added a Diamond to his Gold C, and placed him 20th after the first event. A spoiler mechanism failure just before release made an immediate landing necessary and kept the author on the ground for a valuable three hours. Gliders were scattered all over north-east France, with Quadrado of the Argentine the farthest at 268 miles and MacReady a close second with 242 miles.

July 2nd saw all gliders back on the site, a sky rung with towering clouds, and a fresh north-west wind. Launching was delayed till two pm and was mostly unsuccessful the first and second time around. Finally a major thunder storm swept over the airport as the sailplanes were hastily hauled into some sort of order and launched for a last try. Twenty pilots flew into the dark underbelly of the cloud and climbed inside in powerful lift. Juez of Spain came out the highest at 26,000 ft and dove for the goal 62 miles away. Ivans of the U.S. and Wills of England were a little lower at 21,000 ft and even then Wills had to ridge soar to find his way into the goal airport of Feurs by St. Etienne. The author went to 7,000 ft in the smooth lift of the cloud, lost the rising air, and spent the next half hour in snow, turbulence and downdrafts before finally breaking clear on course and 20 miles out. Ridges and prayers kept the Bréguet up for another 13 miles, resulting in a sudden landing on the side of a hill, half way to the goal and in 14th place for the day. Frank Brame slid along under the clouds and made a few miles less, but closer to the track for 19th position. In this contest all task events

required a landing within 2 km of the track to avoid a point penalty, amounting nearly to the distance that the landing was off the track.

On July 3rd, the north wind at St. Yan was complemented by the classical Mistral wind in the Rhône valley. This is a turbulent, ground-hugging wind that sweeps down past Switzerland and builds standing waves from Lyon to the Mediterranean. The Committee set a fixed course from St. Yan to Cuers and beyond the few kilometers to the Mediterranean. The Canadians managed to cross the 3,000 ft hills into the Rhône Valley and soar in weak turbulent thermals over the rough river country to where the Drôme comes in from the east. The Bréguet was ridge soared near wooded and rocky slopes of the foothills, finally gained enough height to dive into the valley beyond, and had to land minutes later almost in the picturesque village of Jaou, 132 miles from St. Yan. Brame was almost as far having come down near Crest on the Drôme. Ivans, Wills and Saradic of Yugoslavia picked up wave conditions after ridge soaring in the same area and eventually reached Cuers with 10,000 ft in hand. MacReady, the master competitor, went beyond Cuers and landed on a jet fighter base after the runway lights came on. The Canadians had gone about two-thirds of the way and placed 23rd and 27th on that day.

It would be better not to have to record the fourth event, on July 5th. Weak and well spaced thermals should have taken the competitors around a 100 km triangle. Seven pilots made the circuit, but many of the experts came down en route and some, together with the Canadians, never attained enough height with favourable conditions to start.

The weather changed by July 6th, and a late starting, free distance day was specified with the west wind favouring the 100 miles to Geneva. When the day ended, sailplanes were scattered from Geneva to well up and down the Rhône and as far back as St. Yan. The writer came down in the hills at Lamure, 32 miles out and 30th. Frank Brame made it over the ridges to Lyon, more than twice as far, giving him 23rd place for that day.

Sunday, July 8th, produced an amusing attempt to race to Beaune, 55 miles north-east of St. Yan. Thirty-eight sailplanes landed on Paray-le-Monial airfield, just five miles from the start. The author on his second try landed in a field about ten miles out with six others, after making two climbs, one from 1,500 to 1,800 ft, and the second from about 1,100 to 1,300 ft. A ridiculous cross country, but fun, and a relief to return and find that no one had gone far enough to make it a contest day. It was on this day that the Canadian Bréguet crew demonstrated excellent speed. A radio message brought them to Paray on the first try, a few minutes after landing. Nine minutes later the truck and trailer rolled off the airfield on the road to St. Yan. Seven minutes after returning, the ship was ready for take-off and being wheeled into launching position. Some 150 launches were made that day for the entertainment of Sunday spectators and pilots alike.

The next day produced perfect conditions in an Ontario sense, and a race to Moulins and return — 78 miles for the round trip. Unfortunately, a large rain-filled storm mass with no well defined lifting portion swept the area at the Moulins end. Thirty-two sailplanes reached the turn with twenty-six coming back part way. Five landed in one field, two pointing home and three pointing for Moulins. Hanna Reitsch was one of these. The author, who had just scraped into Moulins, watched her make the turn at about 400 ft and glide back on course knowing that a field rather than an airport would await her in another two miles. Frank Brame had stretched his glide to the utmost on the way out and landed the Geier with its poor forward visibility in a roughly furrowed field, thankful that his "undercarriage" was a long smooth skid and not a wheel. The Canadians were 18th and 32nd that day.

Wednesday, July 11th, was similar to the Cuers race day, but under more awesome conditions. The wave producing Mistral wind was blowing at 40 knots on the ground and 70 knots at a few thousand feet. The clouds were just clear of the ridges to the west of the Rhône

Table 1

1956 World Gliding Championship Results

Single-Seater Class

| Pilot | Nation | Sailplane | Final Place Points |
|---|---|---|---|
| MacReady | United States | Bréguet 901 | 4,891 |
| Juez | Spain | Sky | 3,806 |
| Gorzelak | Poland | Jaskolka | 3,576 |
| Saradic | Yugoslavia | Meteor | 3,435 |
| Ivans | United States | Olympia IV | 3,289 |
| Stephenson | Great Britain | Skylark III | 3,142 |
| Ara | Spain | Sky | 3,097 |
| Nietlispach | Switzerland | Elfe PM-3 | 3,081 |
| Hanna Reitsch | Germany | Zugvogel | 3,042 |
| Wills | Great Britain | Skylark III | 3,031 |
| Ortner | Argentina | Skylark III | 2,977 |
| Persson | Sweden | Weihe | 2,887 |
| Bar | Israel | Air 102 | 2,875 |
| Dommisse | South Africa | Bréguet 901 | 2,866 |
| Toutenhoofd | Holland | Skylark III | 2,775 |
| Munch | Brazil | Barros Neiva I | 2,658 |
| Kumpost | Czechoslovakia | VSM 40 Demant | 2,580 |
| Pierre | France | Bréguet 901 | 2,527 |
| D'Otreppe | Belgium | Air 102 | 2,338 |
| Feddersen | Denmark | Olympia | 2,337 |
| Wiethuchter | Germany | HKS 3 | 2,268 |
| Harrer | Austria | Musger 23 | 2,255 |
| Arbajter | Yugoslavia | Orao 2C | 2,169 |
| Gora | Poland | Jaskolka | 2,040 |
| Kalmar | Hungary | ZO 8 Siraly | 2,034 |
| Koch | Holland | Skylark III | 2,029 |
| Lacheny | France | Bréguet 901 | 1,983 |
| Brame | Canada | Geier 2 | 1,889 |
| Cuadrado | Argentina | Skylark III | 1,880 |
| Silesmo | Sweden | Bréguet 901 | 1,810 |
| Oda | Japan | Bréguet 901 | 1,671 |
| Dubs | Switzerland | WLM II | 1,663 |
| Hollan | Czechoslovakia | VSM 40 Demant | 1,509 |
| Georgeson | New Zealand | Air 102 | 1,396 |
| Cartigny | Belgium | Jaskolka | 1,393 |
| Resch | Austria | Musger 23 | 1,378 |
| Mezo | Hungary | Z 08 Siraly | 1,285 |
| Ames | Canada | Bréguet 901 | 1,265 |
| Heinonen | Finland | Air 102 | 984 |
| Jalkanen | Finland | Pik 3 | 961 |
| Uygun | Turkey | Air 102 | 903 |
| Thomsen | Denmark | Olympia | 836 |
| Da Rosa | Brazil | Barros Neiva | 526 |
| Ferrari | Italy | Eolo 3V.1 | 176 |
| Subasi | Turkey | Weihe | 41 |

**Table 2**
Two-Seater Class

| Pilot | Nation | Sailplane | Final Place Points |
|---|---|---|---|
| Goodhart<br>Foster | Great Britain | T-42B Eagle | 3,828 |
| Rain<br>Stepanovic | Yugoslavia | Kosava | 3,187 |
| Sadoux<br>Bazet | Argentina | Condor 4 | 2,748 |
| Trager<br>Miller | United States | Schweizer 2-25 | 2,684 |
| Rousselet<br>Trubert | France | Brégùet 904 | 2,602 |
| Nowatarsky<br>Sandauer | Poland | Bocian | 2,404 |
| Yaykin<br>Argun | Turkey | Rhonschwalbe | 1,336 |
| Nunez<br>Vicent | Spain | Kranich III | 1,058 |
| Haase<br>Heinzel | Germany | HKS 2 | 1,057 |
| Tandefelt<br>Rautio | Finland | Bergfalke 2 | 795 |
| Brigliadori<br>Fanoli | Italy | Canguro | 752 |
| Sebesta<br>Janek | Czechoslovakia | L 13 Blanik | 364 |
| Ostermeyer<br>Angerer | Austria | Musger 19C | 331 |

and on the hills and mountains across the valley. A race to St. Auban, a famous soaring site 200 miles away and well into the French Alps, was selected by the committee as a fitting ending to a world contest. Seven pilots made the arduous passage. Wills reached the foothills and ridge soared into cloud on an into wind heading and then dove into the valley beyond, breaking clear after crossing the ridge. After several such exploits he found wave lift and reached the goal at 10,000 ft. MacReady, although the last of the seven, completed his outstanding contest flying by ridge soaring under terribly turbulent conditions before finding the wave that took him into St. Auban. Brame found the Geier too difficult to control in the Rhône wind and landed nearly on course at Valence. The author reached Montelimar airport about 36 miles further, but well west of the course. The positions for the day were 16th and 29th respectively. W. S. Ivans crashed the Olympia IV on landing after two hours of struggling on a turbulent ridge wind. A back injury kept him hospitalized most of the summer, but latest reports indicate he will soon return to California and be flying again in a few months.

### FINAL SCORE

The contest ended with Paul MacReady of the United States named World Gliding Champion. Competing in his fifth world contest, he demonstrated beyond doubt that he possessed the ability, meteorological knowledge, all round experience and singleness of purpose necessary to win decisively an international gliding contest.

The final scores and sailplanes used are given in Tables 1 and 2.

### LESSONS LEARNED

The weather was exceptionally good for the purpose of selecting a world gliding champion, as it presented the complete array of soaring phenomena. The Canadians were sufficiently skilled and experienced to be competitive and occasionally beat a recognized expert on Ontario-like days. They were not expert enough to cope consistently with the full range of weather and the tasks chosen, but are now well aware of the deficiencies and know the form their pleasure soaring and competitions must take to improve the chances of a Canadian team in future world contests. They must attempt cross country flights as frequently as possible and not wait for the big days. They should set triangular and other specific tasks for themselves and find untried ridges on which to develop soaring skills in high winds. Wave conditions, already known to exist in several parts of Canada, must be explored and understood and the strong up-currents of the cu-nims must be experienced and used successfully.

### IN CONCLUSION

The pilots, Frank Brame and the writer, are very grateful to their crews for their hard work and willing acceptance of the chores necessary on the ground, and wish to express on behalf of the Soaring Association of Canada a very sincere thanks to the many persons and corporations that made it possible for them to represent Canada at these World Gliding Championships.

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**Choice of Design for an Advanced Turbojet**
***(See pages 322 to 328)***

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# CHOICE OF DESIGN FOR AN ADVANCED TURBOJET†

**by F. H. Keast***

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SUMMARY

This paper studies some of the requirements of an advanced turbojet engine. Factors considered are design pressure ratio, turbine temperature and size with an attempt to assess the effect of these design variables on engine weight and frontal area. After-burning engines are also considered. The results of these studies are then applied to various simplified missions of a military character.

**INTRODUCTION**

A SYMPOSIUM on "Optimization of Power-Plant and Airplane Performance" was held at the 22nd Annual Meeting of the Institute of the Aeronautical Sciences in January 1954.[1] In this symposium attention was directed toward light engines of low frontal area. To quote Mr. Silverstein, "The emphasis in the problem of the supersonic fighter mission must be directed toward obtaining light weight engines, and some slight tolerance may be allowed on values of specific fuel consumption. We must look to see how the design of light weight engines of high thrust capacity can be accomplished." This paper was written in response to Mr. Silverstein's appeal. It considers the effect of size and design parameters on engine weight and fuel consumption.

**COMPONENT DESIGN**

The weight of an engine depends on the size of components necessary to produce the required thrust. Advances in compressor design in the past decade make it possible to pass fifty percent more air through the same frontal area. This in itself is of great assistance in reducing weight. At the same time improved combustion chamber design has permitted an increase of the same order in burning velocity. The turbine has never been too obtrusive in frontal area and can still be designed within the frontal area of the other major components. The net result is that an engine of today can not only provide greater thrust on frontal area but also can be basically lighter because of its reduced size for a given thrust.

Let us consider the compressor in more detail, and particularly the implications of higher pressure ratio. At design pressure ratio all stages will operate close to their best incidence, so that the overall compressor will be as efficient as possible. This occurs for each stage at a certain value of the ratio of axial velocity to blade speed, $V_a/u$. At lower speeds than design the pressure ratio will normally be lower than design, so that the density ratio of the air will be lower. This means that the axial velocity at the front of the compressor (where density is close to ambient density) will decrease more rapidly as speed is reduced than the axial velocity at the back of the compressor. This means that the front stages will tend to increase incidence on the blading while the back stages move towards decreased incidence. Eventually stalling at positive incidence of the front stages usually occurs, although it is conceivable that, with some compressors, stalling at negative incidence of the back stages may occur first. In any case, departure from the design pressure ratio and flow results in a trend towards mismatching of the stages. A compressor can have a wide range of stable operation with some stages stalled but when too great a departure is made from stage matching the compressor as a whole stalls. The departure from design operation and, therefore, the danger of encountering stall increases with the design pressure ratio. The low pressure ratio compressor usually has a smooth curve for the surge line but with high design pressure ratio a surge line kink tends to develop which brings the critical surge condition closer to the normal working line of the engine. The turbine nozzles act as the main control of the working line. During acceleration an increase of fuel is given to the engine with a corresponding increase in turbine inlet temperature. This has the effect of decreasing the density into the nozzles, which is equivalent to a throttling effect on the compressor outlet, forcing the compressor to higher pressure ratio. If the equilibrium working line is already close to surge, this may result in a complete compressor stall. The development of a surge line kink by the use of a high pressure ratio compressor, therefore, leads to poor acceleration characteristics. In the extreme case the equilibrium running line may intersect the surge line, which means that even with an infinitely slow acceleration the engine can never reach its design point but will stall at part speed.

It is apparent that a variable area turbine nozzle would allow the engine to operate at all speeds since the turbine nozzle is the main control on the compressor working line. This however is difficult to achieve as this variable feature would have to be built into the hottest part of the engine and would present severe mechanical problems. Some effect can be achieved by opening the exhaust nozzle of the engine, which tends to drop the compressor working line to lower pressure ratio as long as the turbine is not choked at rotor outlet. An alternative is to decrease the flow through the turbine by opening blow-off or bypass valves in front of the turbine, usually

†Paper read at the Annual General Meeting of the C.A.I. in Montreal on the 3rd May, 1956.

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located at compressor outlet or part way along the compressor so that hot gases do not have to be handled. This presents a problem in discharging the blow-off air in the usual tight nacelle. Another solution is to vary the compressor blading. The stators are the obvious choice as the mechanical complication is less. The inlet guide vane is the usual solution although higher pressure ratio compressors may require that other stators may be swivelled. The last and probably most effective solution is to allow the back end of the compressor to run at a different speed from the front end. This is the split compressor, two spool or double compound compressor. "Split compressor" is the description that is most general as there is no reason, other than complication, why we should not have three spool or even four spool compressors. If the two (or more) split compressors are free to vary their speeds according to their needs, they automatically tend to adjust themselves to provide permissible incidence on their blading. If as we reduce speed from design the back end of the compressor does not reduce speed as much as the front end, this will tend to improve the stage incidence of both compressors. Fortunately the laws of nature are with us here and this is what happens. As the pressure drop across a multi-stage turbine decreases, the front stages develop relatively more work than the last stages. As the front stages of the turbine drive the back stages of the compressor for obvious mechanical reasons, the high pressure component tends to maintain its speed more than the low pressure component. Thus the two spool compressor remains in match much better than the single spool engine, where the back end is forced to turn at the same speed as the front end. On basic design there is another advantage of the split compressor engine. It is necessary for high air swallowing capacity for the front stages to rotate slowly. If there is a direct mechanical coupling between the front and back of the compressor the work is limited on the back stages. If, however, the back of the compressor can rotate faster than the front more work can be done. In a specific case it was found that splitting the compressor would allow the same work to be done in 10 stages as could be done in 14 stages of a single spool compressor. A reduction in the number of compressor stages is useful in reducing weight and this has led to the use of constant outside diameter compressors in order to keep the speed high on the rear stages with consequent more work potential. This is a dubious practice if frontal area is important, because of the requirement for close-coupled engine driven accessories such as fuel pumps, oil and hydraulic pumps, generators etc., not to mention control units, starters and other engine mounted units. There are only two places to hang this bulky equipment—one is in the nose bullet which is becoming progressively smaller in the struggle for greater air flow; the other is on the outside of the engine which adds to the frontal area. The waisted compressor with reduced diameter at the rear permits accessories to be tucked in with a minimum addition to frontal area. The alternative is to rely on the aircraft man to find a space for remotely driven accessories, which to a large extent nullifies by the weight of the drive any gain made by saving a compressor stage. The waisted compressor also has the advantage of providing a more symmetrical flow into the outlet diffuser to the combustion chamber. This helps the combustion man to provide a good temperature profile at outlet from his chamber which in turn gives benefits in improved turbine efficiency and life.

In this section most of the discussion has been centred on the compressor as the overall design concept is very closely related to what type of compressor is used. An apology is offered to the combustion and turbine designers for lack of attention to their problems.

**AFTERBURNING**

Afterburning is a most powerful method of increasing thrust, especially at high flight speeds. Because of turbine material limitations it is not possible to put all the fuel that can be burned with the oxygen available ahead of the turbine. We must, therefore, add additional fuel at a less efficient point in the thermodynamic cycle. In addition to this inefficiency, the dynamic head in the afterburner will be higher than that in the main combustion chambers if the afterburner is to be kept to an acceptable frontal area. This will result in a greater fundamental heating loss—at a poor place in the cycle to have it.

The overall effect is that we attain more thrust at a lower specific fuel consumption if we can burn fuel ahead of the turbine rather than behind it. To give an example, if we raise the turbine inlet temperature from 1200°K(2160°R) to 1300°K(2340°R) and still employ the same afterburner temperature, this means that roughly the same amount of fuel is burned but more of it at the highest pressure point in the cycle. At Mach 1.5 the increase in net thrust would be about 5% with a corresponding reduction of specific fuel consumption.

Besides its inefficiency the afterburner also can be the bulkiest component of the engine. The reason is that the heat addition causes a flow Mach number increase across the burning section which becomes greater as more fuel is burned. Because of this the high boost afterburner may have greater frontal area than the main engine. This does not mean that we should relax our efforts to reduce the main engine frontal area because (a) there will always be aircraft applications which do not need an afterburner and (b) reduction of main engine size brings weight benefits.

Table 1 gives some important values for afterburning at Mach 2.5 to a temperature of 1900°K(3420°R) with an afterburner Mach number of 0.3 and a turbine inlet temperature of 1300°K(2340°R). The table shows that it is not possible at this burning Mach number to hide the afterburner behind the engine. Added to this frontal area is the area required for passing cooling air over the afterburner. It will be seen that specific thrusts of the order of 77 lb/lb/sec are theoretically obtainable, but this assumes fully expanded flow by means of a convergent-divergent nozzle. Looking however at the final nozzle area to attain this thrust, we find that in all cases it is at least 2.3 times the engine frontal area. In the case of engines of pressure ratio less than 6 and those greater than 16, even the throat area of the nozzle exceeds the engine frontal area. We are forced to conclude from this that thrusts in practice will be limited to values between 60 and 65 lb/lb/sec and that specific fuel consumption will be correspondingly increased. Another

TABLE 1
Performance of Afterburning Engines at Mach 2.5

Pressure recovery 0.75.
Turbine temperature 1300° K (2340° R).
$A_1$ is compressor frontal area.

| Pressure Ratio S.L.S. | 4 | 6 | 8 | 12 | 16 |
|---|---|---|---|---|---|
| DRY | | | | | |
| Sp. Thrust con-div | 36.3 | 38.0 | 37.5 | 32.0 | 25.0 |
| S.F.C. | 1.84 | 1.64 | 1.50 | 1.42 | 1.47 |
| Sp. Thrust con | 26.7 | 25.5 | 23.5 | 19.2 | 14.5 |
| AFTERBURNING TO 1900°K (3420°R) | | | | | |
| Sp. Thrust con-div | 67.0 | 73.5 | 76.5 | 77.0 | 73.5 |
| S.F.C. | 2.47 | 2.32 | 2.23 | 2.23 | 2.36 |
| Sp. Thrust con | 55.5 | 57.5 | 59.0 | 59.5 | 58.5 |
| S.F.C. | 3.01 | 2.90 | 2.85 | 2.88 | 2.96 |
| Burning area/$A_1$ | 1.96 | 1.42 | 1.18 | 1.09 | 1.19 |
| Nozzle throat area/$A_1$ | 1.30 | 1.00 | 0.86 | 0.87 | 1.00 |
| Final nozzle area/$A_1$ | 2.75 | 2.48 | 2.34 | 2.34 | 2.48 |

point that may be seen from Table 1 is that, whereas the lowest pressure ratio engine needs a variation of 31 per cent for the nozzle throat between non afterburning and afterburning, the higher pressure ratio engines need over 60 percent which adds to the complexity and weight of the nozzle.

**EFFECT OF MATERIALS ON ENGINE WEIGHT**

To date the common materials used in the compressor have been aluminum or steel for blading and discs, with magnesium as a further possibility for the casings. For low speed flight the innovation of resin bonded fibre glass offers interesting possibilities for weight saving, in particular for the rotating parts where centrifugal stiffening will offset the high deflections under load caused by its low modulus. Stator blades would certainly have to be shrouded to avoid the high deflection under gas loads causing fouling with the adjacent rotating rows. At high flight speeds fibre glass, magnesium and aluminum cannot be used because of the severe reduction of their properties with increasing temperature.

Fortunately the development of titanium is now sufficiently advanced to allow its use for this application. With about the same strength as the steel blade and disc alloys, it has only 0.59 of the density of steel. The saving in weight on rotating parts, however, is much greater than indicated by the density ratio. If the blading is changed from steel to titanium the load to be carried by the disc is reduced by 41 per cent. This means that a much lighter disc can be employed. In Figure 1 is shown a titanium disc which weighs 16 lb and supports a total weight of 17 lb of titanium blades. Also shown is the equivalent disc in steel to support the same blades but in steel. The blade weight is now 29 lb and the disc weight 48 lb, a total weight of 77 lb as against 33 lb in titanium or a saving of 57%. The lighter rotor brings additional gains in lighter static members because less stiffness need be built into the supporting structure. At the same time the reduced moment of inertia lowers gyroscopic loads and improves starting and acceleration times.

Considering the turbine end of the engine, any improvements in high temperature properties of the nickel and associated alloys will, of course, result in lighter components. Alternatively the same components may be run hotter so that greater thrust can be achieved from the same airflow. Using this approach an increase in specific fuel consumption may result but a smaller engine is required for a given thrust with consequent saving in weight. Another approach to achieve the same end is to incorporate blade cooling. At Mach 1.5 an increase in turbine temperature from 1200°K(2160°R) to 1300°K (2340°R) will result in a 15% thrust increase for the same airflow at the expense of only 2.5% in specific fuel consumption.

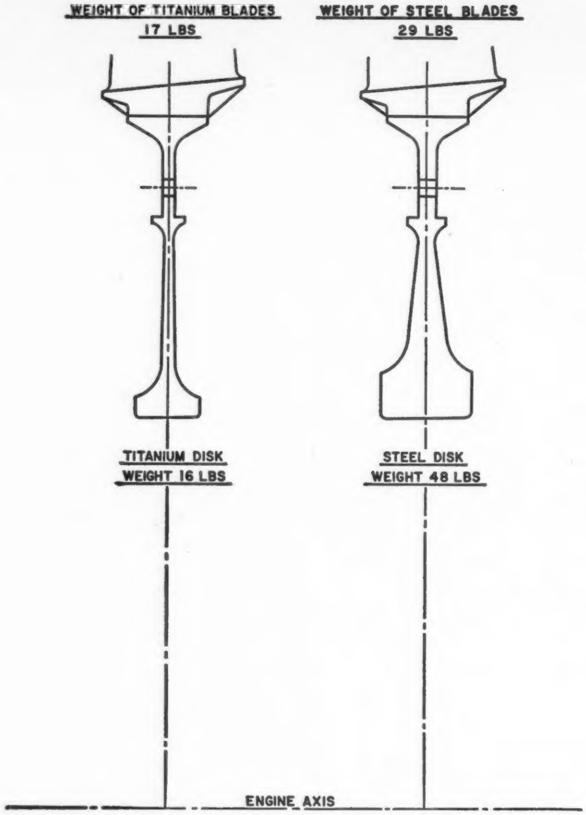



**Figure 1**
**Titanium and steel discs for the same duty**

**ENGINE SIZE**

In spite of the proposals for light weight fighters, the present trend is towards bigger and heavier aircraft both military and civil. The size of fighter armament has been steadily increasing and, with the change from guns to missiles, the trend is still continuing. As missiles become more sophisticated, passing from pure ballistics to the active self guiding type, they become bigger and more complex. At the same time the kill probability of an individual airborne missile is still low enough that a number of missiles must be carried to increase the probabilty of a hit. With respect to the bomber, the nuclear bomb means a lower bomb weight as compared with the bomber at the end of World War II, when a Lancaster was carrying a 22,000 lb bomb. However, increases in required range, speed and altitude, together with loads of electronic equipment for navigation, defence and bomb aiming, all lead to a bomber size which dwarfs that of

World War II. The size of transport aircraft, both civil and military, is still increasing. All of this indicates that engines must be bigger too, unless a multiplicity of small engines is used.

In the symposium referred to in the introduction, Mr. Heinemann of Douglas felt that, if a big enough engine were available, the single engined installation for fighters results in "the lightest and most efficient installation". At the other end of the scale the Boeing B-52 employs eight engines. I am sure that if engines of sufficient size were available the designer would prefer a fewer number, not to mention the flight engineer. For these reasons it appears that the present need is for an engine of at least 20,000 lb dry thrust. With this in mind a study of the effects of engine size on weight and performance follows.

For geometrically similar engines the thrust should vary as the square of the linear dimension while the weight should vary as the cube, giving rise to the square-cube law. The same law defines the maximum size of spiders which breathe through their skins. At a certain size the ratio of mass to breathing area sets a limit on the size of the spider. The only way that he can exceed the limit is to stop being a spider. The same law has been invoked to prove that aircraft above a certain size could not possibly fly. Aircraft have always exceeded the predicted limit by becoming different types of aircraft. With respect to jet engines the square-cube law would state that

$$W_e \propto L^3$$

$$F \propto L^2$$

or combining the relations to give a thrust/weight ratio

$$\frac{F}{W_e} \propto \frac{1}{L}$$

Here $W_e$ is the engine weight, $F$ is thrust and $L$ is any linear dimension. In practice two factors modify this relationship.

**EFFECT OF SIZE ON ENGINE WEIGHT**

An increase in size can allow refinement in structure. For example, a casting when it reaches a certain size can be replaced by a sheet metal fabrication. Or, looking in the oposite direction, a casting cannot be reduced indefinitely in size and retain the same geometric similarity. Eventually the walls of the casting become so thin that liquid metal will not flow into the mould. A minimum wall thickness, therefore, limits the validity of the square-cube law. In a similar way, sheet metal cannot be reduced in size and retain geometric similarity. At a certain scale the sheet metal would be so flimsy that the engine would not withstand normal handling.

Statistical examination of engines cannot reveal the proper factors here because the engines available for analysis are relatively few and have been designed and developed by different teams of varying competence and design philosophy.

Figure 2 has been prepared from published data available on current axial flow jet engines. Missile and short life engines have been omitted. The square-cube law has been shown across this plot. The difficulty of determining amongst this scatter of points the nature of the practical law is evident.

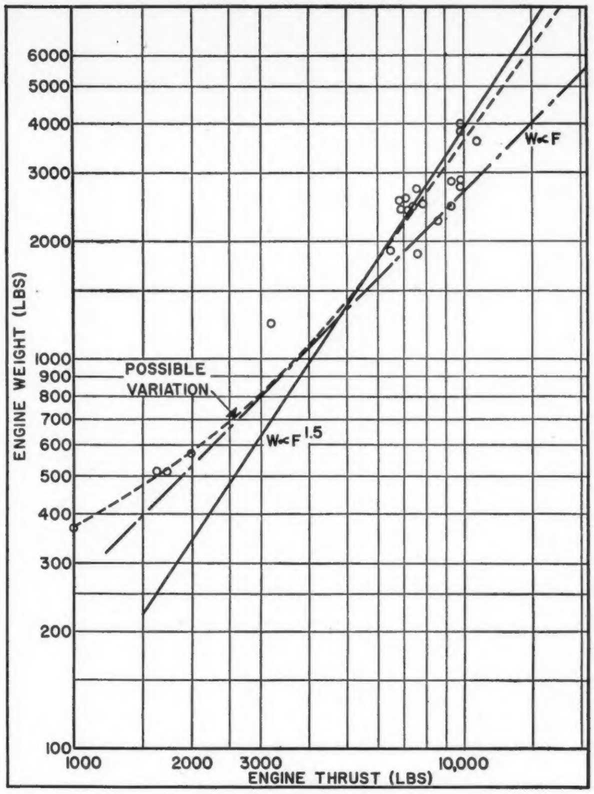



**Figure 2**
**Engine weight and thrust**

From a design study made at Orenda Engines Limited of two engines of different thrust but otherwise as similar as practical limitations would permit, it appeared that the cube law for basic engine weight with no accessories is replaced in practice by a 2.7 power law for engines of the order of 20,000 lb dry thrust. Newton[2] quotes a value of 2.5 but does not state the size of engine on which his studies were made. The Orenda design study would indicate that this index was about right for engines of 12,000 lb thrust. It is reasonable to expect that as engine size increases the weight law will approach the value of the cube law since eventually all design changes to cheat the cube law will have been exploited.

To the weight derived by such a law must be added the accessory weight, which will be about the same for any given aircraft application. Taking the value derived from the Orenda design study across the appropriate range and having as a guide the few engines in the 1,000 lb to 2,000 lb range, a possible variation of weight with thrust has been indicated by the dotted line in Figure 2. This would mean that a minimum weight/thrust ratio occurs at about 3,500 lb thrust, so that no weight advantage could be expected for engines smaller than this. This value should not be taken too seriously, as estimates have varied from thrusts much lower than this up to thrusts as high as 8,000 or 10,000 lb. For the purpose of weight analysis which follows, the index 2.7 was taken to apply to the engines under study as all were considered to lie in the 15,000 to 25,000 lb bracket.

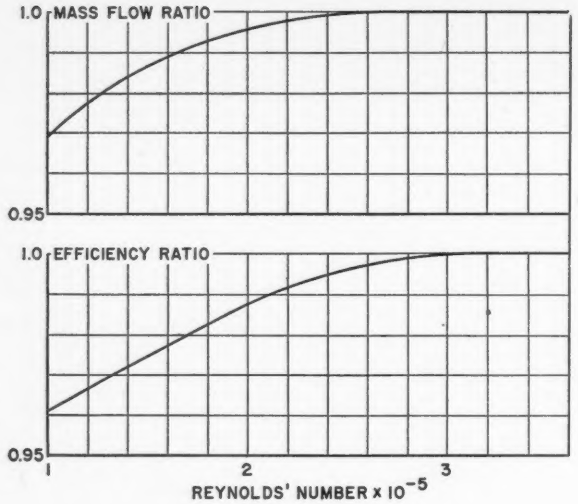



**Figure 3**
**Effect of Reynolds' number**

## EFFECT OF SIZE ON PERFORMANCE

The section above modified the index of the square-cube law by virtue of the practical changes to the equation

$$W_e \propto L^3$$

The size of the engine also affects the performance which results in modification to the equation

$$F \propto L^2$$

Figure 3 shows test results of an Orenda compressor plotted against the Reynolds' number of the first stage rotor blade based on chord and relative velocity at mean blade height. At sea level most engines have blading operating above the critical Reynolds' number at take-off rating but, at altitude, deterioration of performance can be expected. For example an engine which at the test bed gives 20,000 lb might have a first stage Reynolds' number of 230,000 at 50,000 ft, 400 knots at its cruise rating. Figure 3 shows that Reynolds' number deterioration is just starting to occur at this altitude. Mass flow will be almost unaffected but compressor efficiency will be 0.6% lower than its sea level value. A geometrically similar 10,000 lb rated engine will have a Reynolds' number of 162,500 under the same flight condition and will have lost 1% in mass flow and 2.2% of its sea level efficiency.

The other factor which relates performance to size is that of tolerance. With existing techniques a large blade can be made with greater accuracy than a small one so that a better efficiency can be expected from the bigger engine.

Inclusion of these effects would result in further modification of the square-cube law in favour of the large engine.

## EFFECT OF PRESSURE RATIO ON ENGINE WEIGHT

As remarked earlier with respect to size, the number of engines covering a range of pressure ratio are so few as to preclude the possibility of a statistical analysis, as the results would be affected by the design team and the state of technological progress. For this reason an attempt has been made to assess what the same design team might do at the same state of progress. The assumption was made that certain weights in the engine are independent of the pressure ratio of the engine and other weights are affected by the number of compressor and turbine stages. The Orenda 11 was taken as the basic engine since a complete breakdown of the weights of components was available. The weight of compressor stages including the related casing, spacers, drums etc., was evaluated so that the weight per stage was based on a slice through the engine. Similarly the weight of the two stage turbine was evaluated to give the weight of each stage. An analysis was made of the number of compressor stages that could be driven by one turbine stage. All compressor stages which employed aluminum were changed to steel as the analysis was to be biased towards high speed flight where aluminum fails because of temperature. The weight of the variable components was increased by 50% to allow for the heavier shafts, bearing assemblies and structures, which were affected by the greater torque resulting from the higher horsepower to be transferred from turbine to compressor. The resultant equation for engine weight was of the form

$$W_e = A + 1.5\ [B(N-1) + C(n-1)]$$

where $A$, $B$ and $C$ are constants, $N$ was the number of turbine stages and $n$ the number of compressor stages. $A$ includes the weight of the first turbine stage and the first compressor stage. The pressure ratio for differing values of $n$ was estimated together with the value of engine weight. The results are presented in Figure 4. A smooth curve has been drawn through the increments in $n$ as these were small, but discontinuities are shown when an extra turbine stage had to be added as this gave a major increase in weight. The assumption made is that, although the Orenda 11 was designed some years ago, the relationship given in the equation above still applies to engines now projected. A check has been made on the validity of this assumption which indicates that, today, the equation used slightly favours the low pressure ratio engine as the trend seems to be towards reduction of the assumed constant $A$ relative to the values of $B$ and $C$. This indication was not sufficiently significant to be allowed for in the analysis.

A check was made of the engine weights derived by

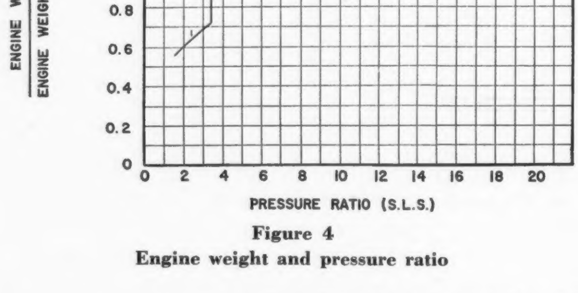



**Figure 4**
**Engine weight and pressure ratio**

this method against Silverstein's values shown in his Figure 3.[1] Apart from the discontinuities caused by the addition of turbine stages, it lay very close to Silverstein's curve and, in fact, was almost identical over the range of pressure ratio from 8 to 12. It was more favorable to the low pressure ratio engines because of the deletion of a turbine stage and somewhat less favorable to the high pressure ratio engines giving a value of 675 lb/ft$^2$ as against about 640 from Silverstein's curve for an engine of rated pressure ratio 15. Silverstein, in pointing out the requirement of low weight for a supersonic fighter, based his estimates on a most thorough mission analysis for such a fighter. It is beyond the scope of this paper to attempt such an analysis but the last three figures of this paper present the effects of engine design pressure ratio on the cruise part of a long range mission without afterburning. In all cases the weight of the engines was taken as dependent on two factors, (a) the pressure ratio weight factor of Figure 4 and (b) a size factor taken as the 1.35 power of the mass flow, all engines being assumed to have the same mass flow per square foot of frontal area. This makes use of the 2.7 power law of weight mentioned above.

**EFFECT OF PRESSURE RATIO ON PERFORMANCE**

If turbine cooling is not employed, present materials limit turbine temperatures to the order of 1200°K (2160°R). Figure 5 shows the specific thrust of engines of different design test bed pressure ratio when operating at altitude. Figure 6 shows the specific fuel consumption of the same engines. It is readily seen that the high pressure ratio engines suffer a greater loss of specific thrust as Mach number increases. This is because the compressor delivery temperature increases with Mach number so that a lower fuel/air ratio can be used for a fixed value of turbine temperature, and this delivery temperature is greater for the higher pressure ratios. To match an aircraft drag the engines of lower specific thrust must swallow more air and therefore be bigger.

**RANGE ESTIMATES**

The cruise performance without afterburner of aircraft with engines of different design pressure ratios has been considered. In each case the drag of the aircraft was assumed unaffected by the choice of engine. Three

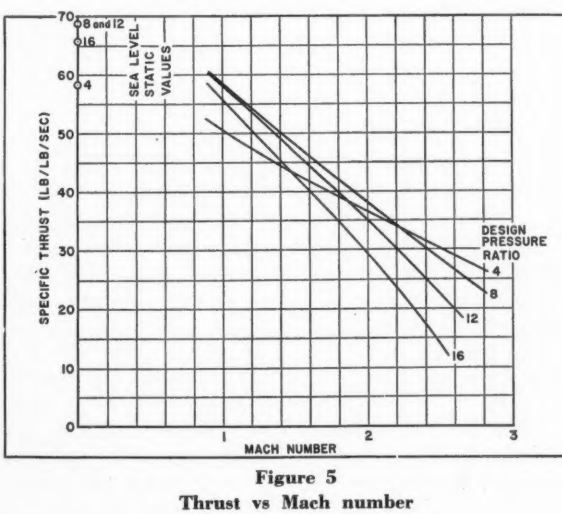



**Figure 5**
**Thrust vs Mach number**

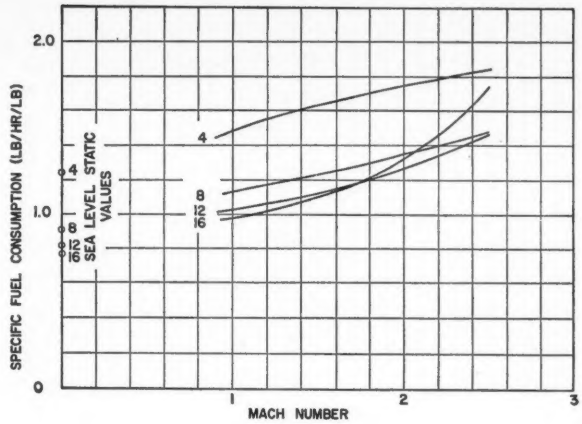



**Figure 6**
**Specific fuel consumption vs Mach number**

aircraft were considered, all with engines of about 20,000 lb take-off rating.

(a) Cruise at Mach 0.9 commencing at 40,000 ft. The engines were assumed to cruise at a turbine temperature of 1000°K (1800°R). Lift/drag ratio was taken as 16 and an aircraft weight of 62,000 lb per engine. At this cruise Mach number the cruise combustion temperature would be below the take-off value if acceptable take-off performance is to be obtained. The engine performance was estimated with the engines cut back to an operating pressure ratio equal to the sea level static value.

(b) Cruise at Mach 1.5 commencing at 50,000 ft. Turbine temperature was 1200°K (2160°R). Lift/drag ratio was 6 with an aircraft weight of 30,000 lb per engine. Because of the higher cruise speed, the higher cruise altitude and combustion temperature are necessary. Because of the higher drag than that in the subsonic cruise case, the take-off and cruise temperatures are more nearly equal. To cruise at this value of turbine temperature some turbine cooling is necessary with present materials. This cooling should permit about 1300°K (2340°R) for take-off.

(c) An advanced aircraft cruising at Mach 2.5 commencing at 60,000 ft. Turbine temperature was taken as 1300°K (2340°R). Lift/drag ratio was taken as 6 with a weight of 33,000 lb per engine. An uncooled turbine is hardly feasible for this type of aircraft and take-off might be at an even higher turbine temperature (possibly higher than 1400°K or 2520°R.). If 1300°K is possible for cruise, 1400°K for take-off is reasonable because the turbine cooling air will be at a much lower temperature at take-off. At Mach 2.5 the engine intake temperature is 70 percent greater than at take-off. It may even be necessary to refrigerate the turbine cooling air at these high Mach numbers, the refrigerating requirements increasing with engine pressure ratio as the compressor delivery temperature approaches combustion temperature.

For each case two engine weights are used. The first represents a reasonable improvement on present opera-

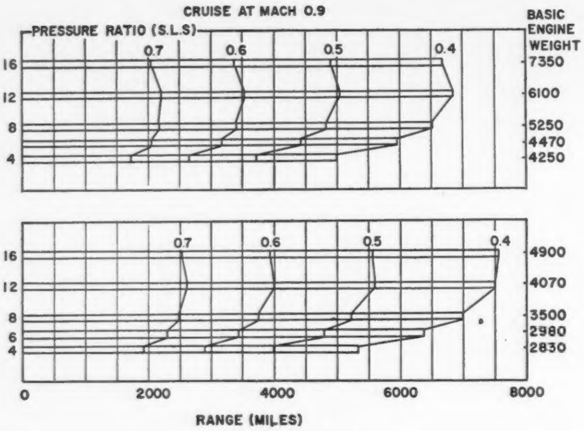



**Figure 7**
**Range at Mach 0.9**

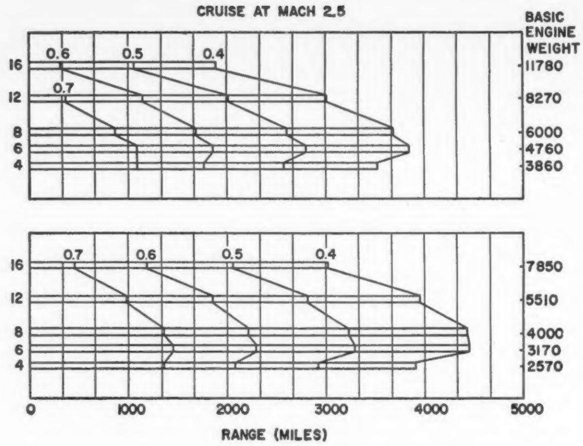



**Figure 9**
**Range at Mach 2.5**

tional engines giving a weight/thrust ratio of 0.28 for the subsonic engine of pressure ratio 8. This means that improvements have been incorporated which allow current values of weight/thrust to be achieved by a larger engine in spite of the square-cube law.

The basic weight of this engine is shown in Figure 7 to be 5,250 lb. To this must be added the systems and accessories which will bring the weight up to about 5,600 lb. The second set of charts shows the influence of reduction in basic weight by one third, which is felt to be attainable by advanced design concepts.

The figures shown on the bar charts are values of basic aircraft weight at end of cruise to the total aircraft weight at commencement of cruise. The basic aircraft weight includes structure, equipment, crew and payload but does not include engine weight as this is different for each bar chart. A Bréguet climb has been assumed during cruise.

**DISCUSSION OF RANGE ESTIMATES**

In Case (a), Figure 7, it is apparent that, for ranges above 2,000 miles, the pressure ratio 12:1 engine is ahead of its competitors. At extreme range the 16:1 engine has still not offset its initial weight penalty. The lower figure shows that with reduced engine weight the 16:1 engine begins to show advantage at ranges over 6,000 miles. The importance of weight is shown by the example that a light 8:1 engine from the bottom chart shows a range of 7,000 miles whereas a heavy 12:1 from the top chart gives 6,850 miles for the same aircraft basic weight.

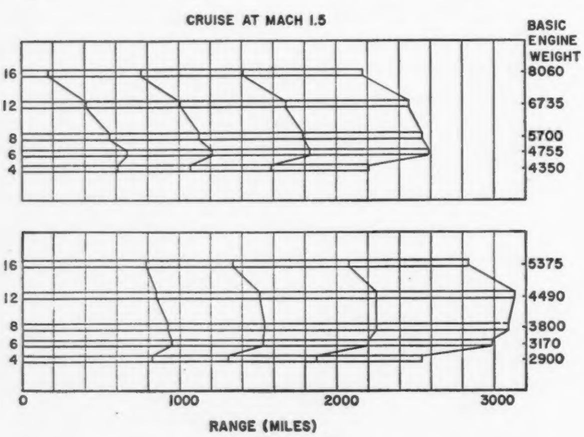



**Figure 8**
**Range at Mach 1.5**

Case (b), Figure 8, illustrates to an even greater extent the influence of engine weight. The 8:1 engine weight was here increased from 5,250 to 5,600 lb to allow for the strengthening and material substitution required by the higher inlet pressures and temperatures. Other engines were modified in the same ratio. In practice the higher pressure ratio engines would suffer more because their high compressor delivery temperature would exclude the use of light materials over a greater number of stages. Here we see that at the higher engine weights the greatest range is achieved everywhere with the 6:1 engine. When engine weight is reduced in the lower chart we see that first the 6:1 engine leads up to about 1,000 miles; it is then surpassed by the 8:1 engine and finally the 12:1 engine begins to show advantage above 2,250 miles.

In Case (c), Figure 9, with cruise at Mach 2.5 the 8:1 engine was further increased in weight to 6,000 lb because of the even higher inlet temperatures. In this case the 6:1 engine is challenged only by the 8:1 engine at ranges above 4,000 miles.

**CONCLUSIONS**

The need for light compact engines for supersonic interceptors is readily evident. This paper has shown that the same type of engines can bring benefit to long range missions.

It is evident that no single engine can be optimum over the range of conditions studied here unless it has a distinct weight advantage over its contemporaries. An engine of intermediate pressure ratio which possessed this advantage would have a wide range of application. At the same time the possibility exists of producing variants of the engine for widely different applications to bring it closer to the optimum performance for a given mission. A two spool engine has an advantage here in that relatively minor blading changes can alter the matching of the two compressors. This means that, for example, mass flow may be exchanged for pressure ratio or vice versa, in order to optimize the engine for different applications.

***For References see page 321***

# INTER-INDUSTRY RELATIONSHIP OF THE AIR TRANSPORT INDUSTRY†

**by Dr. A. Jaworski***

***Department of Transport***

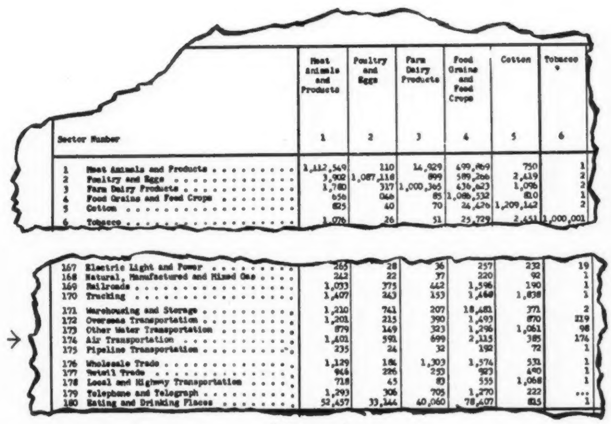
## INTRODUCTION

DURING the last twenty-five years, Professor Wassily W. Leontief of Harvard University, assisted by several teams of economists and mathematicians, has been analyzing the statistics of the relationship of all major branches of United States industry.

The interdependence of different branches of the national economy was clearly recognized by the French physiocrats of the eighteenth century when they constructed the so-called "Tableau Economique". Professor Leontief has been the pioneer among contemporary economists who by using modern statistical methods and tools, including electronic computers, and applying them to the available data of all major industries, has investigated the dependence of each industry on the others. Leontief's first complete investigation of the subject was published in 1941 under the title, "The Structure of the American Economy, 1919-1929".[a]

Following his example, there have been other groups at work in the United Kingdom,[1] Canada, France, Holland, Italy, Israel and Norway and the literature on the subject (some of the works are highly mathematical) runs into hundreds of publications.[2 3]

The results of the analyses are usually presented in table form, like a mileage table on a road map – fragments of the U.S. input-output tables for 1947 are reproduced in Figure 1 for the sake of illustration. Suppose we have decided to divide the national economy into 200 separate sectors[b] comprising 198 industries or industrial groups and two groups called "household" and "government", these last two providing the ultimate balance. Along the left-hand side of the table, the 200 sectors are illustrated in a vertical column, one sector to a row, and across the top of the table the same sectors are repeated in the same order, each one heading a separate column. This leads to a grid where each square



| Sector Number | Meat Animals and Products 1 | Poultry and Eggs 2 | Farm Dairy Products 3 | Food Grains and Feed Crops 4 | Cotton 5 | Tobacco 6 |
|---|---|---|---|---|---|---|
| 1 Meat Animals and Products | 1,112,549 | 110 | 14,929 | 499,469 | 750 | 1 |
| 2 Poultry and Eggs | 3,902 | 1,087,118 | 899 | 589,266 | 2,419 | 2 |
| 3 Farm Dairy Products | 1,780 | 317 | 1,000,365 | 436,623 | 1,096 | 2 |
| 4 Food Grains and Feed Crops | 656 | 046 | 85 | 1,086,532 | 810 | 1 |
| 5 Cotton | 825 | 40 | 70 | 24,426 | 1,209,142 | 2 |
| 6 Tobacco | 1,076 | 26 | 51 | 25,729 | 2,451 | 1,000,001 |
| 167 Electric Light and Power | 265 | 28 | 36 | 257 | 232 | 19 |
| 168 Natural, Manufactured and Mixed Gas | 242 | 22 | 37 | 220 | 92 | 1 |
| 169 Railroads | 1,033 | 375 | 442 | 1,596 | 190 | 1 |
| 170 Trucking | 1,407 | 243 | 153 | 1,460 | 1,838 | 1 |
| 171 Warehousing and Storage | 1,210 | 741 | 207 | 18,481 | 371 | 2 |
| 172 Overseas Transportation | 1,201 | 215 | 390 | 1,493 | 870 | 119 |
| 173 Other Water Transportation | 879 | 149 | 323 | 1,296 | 1,061 | 98 |
| 174 Air Transportation | 1,401 | 591 | 699 | 2,115 | 385 | 174 |
| 175 Pipeline Transportation | 235 | 24 | 32 | 192 | 72 | 1 |
| 176 Wholesale Trade | 1,129 | 186 | 1,303 | 1,574 | 531 | 1 |
| 177 Retail Trade | 946 | 226 | 253 | 923 | 490 | 1 |
| 178 Local and Highway Transportation | 718 | 45 | 83 | 555 | 1,068 | 1 |
| 179 Telephone and Telegraph | 1,293 | 306 | 705 | 1,270 | 222 | ... |
| 180 Eating and Drinking Places | 52,457 | 33,144 | 40,060 | 78,407 | 815 | 1 |

**Figure 1**
**Illustrating Input-Output Tables**

stands for both an input and an output. An input may be defined as any expense necessary to complete the production of an output. Each square is an input to the sector named at the top of the column in which it appears and an output of the sector named at the left of its horizontal row. The total inputs and outputs of each sector in its column and row will always be in balance as in double-entry bookkeeping.

The point of this construction is to show the contribution of every sector to every other sector simultaneously in two forms – what it supplies and what it obtains. By such presentation it is possible to find out the total contribution, namely the direct and the indirect. For example, if the air transport industry forms one of the sectors, it is relatively easy to find out what the air transport industry spends directly for trucking, either in operating its own fleet of trucks or hiring outside trucking service. But there is also an indirect contribution by the trucking industry to the air transport industry, since several suppliers to the air transport industry use trucks extensively and some part of their trucking services must be allocated to air transport. It is, therefore, necessary to obtain figures that reflect all the activities of the suppliers to the air transport industry and, in practice, with the necessary cross-check, this leads to the analysis of all sectors of the country's

†Received 16th August, 1956. The views expressed in this paper are the author's and do not necessarily represent those of the Department of Transport.

*Economist.

[a]Now re-issued in an enlarged edition as "The Structure of the American Economy, 1919-1939", Oxford University Press, New York, 1951.

[b]Leontief started first with a division into 11 major sectors only but a set of tables for the U.K. economy, to be published shortly, will carry the division into 450 separate sectors.

economy. In many instances, the indirect contribution – as will be shown later – exceeds the direct.

If the information is presented in a numerical form – usually dollars, to allow the addition of different physical units – it is possible to estimate which industry will be affected to what extent when the output of any industry shown on the table has been increased or decreased by a known amount. Of course, this information may be of great value in planning larger undertakings to fight unemployment or to switch over some part of an industry from peacetime production to a state of national emergency or vice versa.

There are several difficulties involved in an analysis on so large a scale. First, if the national economy is divided into $N$ sectors, at some stage of the calculation $N$ equations must be solved and when the number of equations goes into the hundreds, even though an electronic computer may handle the arithmetic correctly, the solution cannot be accepted until the order of magnitude of the errors involved in the basic data and the purely mathematical properties of the computation process have been established.[c] The necessary number of multiplications is of the order of $N^3$; for a 200 sector division, it runs into eight million. Even with large-scale electronic computers, the speed with which information can be supplied to and taken from the equipment, the capacity and access time for internal storage of information and coding difficulties may be more critical for some problems than the actual computation time. Furthermore, in practice, the collection of basic data can be carried out only during a country's census of industry.

The last available data on United States input and output were based on the analysis of the 1947 Census of Industry, supplemented later by special enquiries, and were published by the U.S. Department of Labor in the autumn of 1953 in the form of sixteen sheets of tables, as illustrated in Figure 1. Each sheet is 20 × 15 inches and the tables are in small print – the figures cannot be reduced further for normal reading without magnifying equipment. The tables are accompanied by a classification manual of the industry and a mimeographed bulletin with comments on each sector. The U.S. government spent several million dollars on this project. However, Professor Leontief intends to bring the 1947 grid up to date by means of the 1954 Census of Manufacturers, for the relatively small cost of $250,000, "because it will be like correcting a road map after the basic map has been made".[6]

The object of this paper is to present and discuss the relationship of the air transport industry to other industries by extracting figures from the U.S. input-output tables for 1947 and amplifying them from other sources mentioned in the footnotes and References.

[c]N. Wiener, the well-known mathematician of M.I.T., has warned that "the use of machines for the solution of twenty or thirty simultaneous equations shows difficulties which do not arise when we study analogous problems of small order . . . these may completely deprive the solution of any significant figures whatever . . . ".[4] Professor O. Morgenstern of Princeton University has added, "The equality of the numbers of unknowns and equations is, in general, neither a necessary nor a sufficient condition for the solvability of a system of equations. This can be only ascertained from an investigation of the mathematical properties of the particular system in question."[5]

Obviously since 1947 several changes have taken place, but *The Economist* has this to say about the United Kingdom input-output tables based on the 1948 census and expected to be published this year.

> "It does not follow that, because the input-output table is based on 1948 data, it will be out of date eight or ten years later, because of changes in demand, in price relationships (following devaluation, for example) or in technology. The substitution of one product for another is continually occurring, but over the whole field of industry technological change is slower than is commonly supposed; in America calculations based on 1947 figures have been found to apply closely to conditions in 1952. Allowances have to be made for broad price changes by means of appropriate indices."

This general statement is valid for United States 1947 data, until the air transport industry moves fully into the jet era; when that happens, the 1947 coefficients will definitely require major revision or, better still, complete replacement by more recent data, obtained from a new census.

TABLE 1

U.S. AIR TRANSPORTATION INDUSTRY EXPENSES IN 1947

Source: U.S. Department of Labor, Bureau of Labor Statistics.
Note: Profits are excluded.

| Type of Operator | Operating Expenses Excluding Depreciation | | | | Depreciation and Amortization | |
|---|---|---|---|---|---|---|
| | Amount | | Percentage of Total | | | |
| | $000 | | % | | $000 | |
| Total | | 719,044 | | 100.00 | | — |
| Certified carriers | | 528,047 | | 73.44 | | 68,735 |
| Domestic | 344,217 | | 47.87 | | 45,859 | |
| International | 183,830 | | 25.57 | | 22,876 | |
| Non-certified carriers | | 33,511 | | 4.66 | | 1,082 |
| Large irregular | 24,982 | | 3.47 | | 806 | |
| Cargo carriers | 8,529 | | 1.19 | | 276 | |
| Fixed base operators | | 116,426 | | 16.19 | | 17,705 |
| Airports—mostly municipal[d] | | 30,751 | | 4.28 | | Not available |
| Payments to foreign carriers | | 10,309 | | 1.43 | | — |

## CLASSIFICATION OF INDUSTRY

In establishing an inter-industry relationship, a clearly defined classification system is essential. If the whole economy of a country is to be divided into sectors, for the purpose of input-output tables, a sector may be defined as:

(1) a commodity or group of commodities
(2) a group of establishments having in common certain characteristics (such as production of similar commodities, use of the same principal raw material or possession of similar types of equipment)
(3) an activity (such as the activity of providing new residential construction) or
(4) a defined process (such as sand casting of metals).

[d]Federal Government operates only Washington National Airport.

Considerations of the availability of data make it necessary to adhere to an establishment classification for manufacturing industries.

In the U.S. input-output tables for 1947, with a 200 sector division, the air transport industry came under the sector No. 174 (Figure 1), which was defined on a company basis covering United States companies engaged in domestic and foreign air transport, airport and flying field operation and maintenance, including commercial airports operated by the municipalities, and airport terminal services. Transportation of United States passengers and imports by foreign air carriers was included as a competitive import of transport services. Receipts from trade activities, such as the sale of fuel, equipment and parts, were excluded.

**AIRPORTS**

The order of magnitude of each component of the industry is shown in Table 1. In this table, as in others, percentage data can be used as an index. Admittedly the index is very rudimentary, but in most instances a better one is not yet available.

In the table no figures are shown for airport depreciation. This is a serious omission as this cost item is likely to be of the same order as the depreciation costs of the scheduled air carriers.

The latest estimate of the capital investment in U.S. civil airports in 1955 was given in May 1956 by the late C. J. Lowen, Administrator of Civil Aeronautics, as $4 billion.[e] By comparison, the total assets of U.S. scheduled airlines in September 1955 amounted to $1.3 billion — a ratio of 1:3. If we assume a 25 to 30 year write-off period for the airports and an 8 to 10 year period for airline capital assets[7] — a ratio of 3:1 — we may conclude that the actual annual depreciation costs of the airports and airlines are of the same order of magnitude.

In Canada, the capital investment in civil airports may be as high as $300,000,000, whereas the capital assets of Canadian carriers at the end of 1955 were of the order of $113,018,000.

However, in most countries, estimates of airport investment are at best rough approximations, often including wartime expenditures some of which are often of no value to civilian operations; the capital expenses during the post-war period, 1947-1955, are a much more reliable index. In absolute figures, the 1947-1955 capital expenses for civilian airports and navigational facilities amounted to $72,000,000 in the United Kingdom, $96,000,000 in Canada and $560,000,000 in the United States. It is interesting to note that of this $560,000,000, some $451,000,000, almost equally shared by the Federal Government and Municipal Authorities, was spent on airports, while $109,000,000 was provided by the Federal Government for navigational facilities.[8]

Another comment which might be made about Table 1 concerns the airport operating expenses. In drawing up this table, the U.S. Department of Labor has explained that no figures for airport operating expenses were available; the figure given, $30,751,000, is in fact the airport revenues, which were assumed to be of the same order as the operating expenses. This assumption, though doubtless the best that could be made in the circumstances, seems open to question, since even today a significant number of airports in the United States, and even more in Europe and in Canada, are facing operating expenses far in excess of actual revenues. In the "International Airport Charges", published by I.C.A.O. in 1954, for all six major United States airports the expenses for 1949 and 1948 exceeded the revenues. Even today the New York Port Authority, who operate the airports with the highest traffic density in the world, does not obtain a sufficient return on its investment, although it still expects that before the airports are returned to the municipalities concerned, in about 40 years, it will recover all initial investment plus a tidy profit.[9]

In Canada the annual airport and airway maintenance expenses are of the order of $17,000,000, against annual revenues of about $7,000,000.

In short, there is ample evidence that in Table 1 airport expenses (excluding radio and met. facilities) have been substantially underestimated; therefore, in the following tables, where airport expenses are directly or indirectly involved, they will also be under-estimated as they are derived from the totals shown in Table 1.

**MAJOR GROUP OF EXPENSES (INPUTS)**

The 1947 study concerns itself with the "real" flow of goods and services. For example, money flows representing transfers of money for financial claims or for previously existing assets are excluded.

In Table 2 the major group of expenses (input items) are recorded for the air transport industry as a whole, with airport data shown separately in Table 2A, since they are less familiar than the distribution of airline expenses. From the percentage distribution of the expenses in Table 2, it will be noticed that wages account for practically one-half (49.7%) of the expenses (excluding depreciation) and that purchased services and cost of materials are practically equal; each is slightly over one-fifth (22%) of the total expenses. Cost of fuel including electricity, on the same basis, amounts to 10%, or nearly as much as the cost (12%) of all other materials including aircraft and parts.

In the airport expense picture (Table 2A), the cost of buildings maintenance (1.3%) relative to field maintenance (18.5%) is strikingly low. In the United States, as a rule, the hangars are not operated by the airport management and this fact, of course, helps to keep the building costs down in the airport ledgers. On the other hand, at Montreal Airport, where several hangars in addition to two terminal buildings are operated by the airport management, the operating cost of all buildings is almost twice as high as the field maintenance.

**Marketing Charges and Taxes**

It is not generally realized that more than 40% must be added to the producers' prices to cover transportation and distribution charges for many important purchases by the air transport industry. Some figures are given in Table 3.

The marketing charges shown in the summary under the heading "Other Water Transportation" refer to all water transport other than overseas, such as inland water-

[e]Hearings before a Sub-committee of the Committee on Appropriations, U.S. Senate, p. 171, May 8, 1956.

TABLE 2
U.S. AIR TRANSPORTATION INDUSTRY DISTRIBUTION OF EXPENSES
1947
(Thousands of Dollars)

Source: U.S. Department of Labor, Bureau of Labor Statistics.
Notes: 1. Depreciation and profits are excluded.
2. Marketing charges, amortization and taxes are included.

| Expense Item (in order of magnitude) | Amount | | | Percentage of Total Expense (excl. Deprec. & Profit) | | |
|---|---|---|---|---|---|---|
| | | $000 | | | % | |
| Total (excluding payments to foreign carriers) | | | 710,455 | | | 100.00 |
| A. Non-material charges | | | 548,227 | | | 77.16 |
| 1. Wages and Salaries | | 353,082[f] | | | 49.70 | |
| 2. Purchased Services | | 157,041 | | | 22.10 | |
| (a) Imports (non-competitive invisibles) | 47,810 | | | 6.73 | | |
| (b) Non-life insurance | 21,522 | | | 3.03 | | |
| (c) Forwarding and arrangement of transportation | 18,426 | | | 2.59 | | |
| (d) Air transportation | 18,174 | | | 2.56 | | |
| (e) Advertising | 13,414 | | | 1.89 | | |
| (f) Non-farm non-residential rents | 13,109 | | | 1.85 | | |
| (g) Telephone | 10,606 | | | 1.49 | | |
| (h) Auto repair services | 4,671 | | | .66 | | |
| (i) Miscellaneous professional services | 3,684 | | | .52 | | |
| (j) Miscellaneous repair services | 2,322 | | | .31 | | |
| (k) Telegraph | 1,213 | | | .17 | | |
| (l) New & maint. construction | 764 | | | .10 | | |
| (m) Business services n.e.c. | 485 | | | .07 | | |
| (n) Motion picture prod. & service | 352 | | | .05 | | |
| (o) Highway transportation | 148 | | | .02 | | |
| (p) Credit & collection agencies | 125 | | | .02 | | |
| (q) Medical & health services | 111 | | | .02 | | |
| (r) Electrical repair shops | 34 | | | .01 | | |
| (s) Watch, clock & jewellery repair | 31 | | | .00 | | |
| (t) Armature rewinding shops | 24 | | | .00 | | |
| (u) Building maintenance service | 16 | | | .00 | | |
| 3. Taxes Paid | | 38,104 | | | 5.36 | |
| (a) Federal Government | 22,324 | | | 3.14 | | |
| (b) State & Local Government | 15,780 | | | 2.22 | | |
| B. Cost of materials, fuels, electricity and contract work | | | 162,228 | | | 22.84 |
| 1. Cost of materials, parts, containers and supplies | | 89,800 | | | 12.64 | |
| (a) Aircraft engines | 24,104 | | | 3.39 | | |
| (b) Foreign value | 18,939 | | | 2.67 | | |
| (c) Aircraft equipment n.e.c. | 16,148 | | | 2.27 | | |
| (d) Eating & drinking places | 11,462 | | | 1.61 | | |
| (e) Undistributed | 7,798 | | | 1.11 | | |
| (f) Mechanical measuring instruments | 4,110 | | | .57 | | |
| (g) Tires & inner tubes | 3,237 | | | .46 | | |
| (h) Printing & publishing | 1,807 | | | .25 | | |
| (i) Stationery & office supplies | 1,646 | | | .23 | | |
| (j) Manufactured ice | 401 | | | .06 | | |
| (k) Greenhouse & nursery products | 74 | | | .01 | | |
| (l) Apparel | 74 | | | .01 | | |
| 2. Cost of fuels and purchased electric energy | | 72,428 | | | 10.20 | |
| (a) Petroleum refining (fuel oils) | 70,305 | | | 9.90 | | |
| (b) Electric light & power | 1,838 | | | .26 | | |
| (c) Bituminous coal | 131 | | | .02 | | |
| (d) Natural gas | 66 | | | .01 | | |
| (e) Manufactured gas | 66 | | | .01 | | |
| (f) Anthracite coal | 22 | | | .00 | | |

ways, toll ferries and coastal shipping. The amount indicated there, $772,000, is surprisingly high compared with the trucking expenses. It will be noted later on (in Table 4) that, when the indirect influence is accounted for, the air transport industry in the United States is more dependent on water transport than on trucking.

In addition to the significant mark-up on the price of fuel – 42% over the refineries' prices – there is a significant marketing charge on the purchase of tubes and tires – 29%. In an extreme case (although the absolute amount is relatively small) the purchase price of bituminous coal – $131,000 – includes a marketing charge of 197.7%.

[f]Includes in thousand dollars $27,630 as other payments to individuals and $4,148 as contributions and gifts.

**Indirect Requirements**

In Table 4 the contributions of the various industries serving the air transport industry are arranged in order of magnitude. A per million rather than a per centage breakdown has been adopted to avoid entries of less than unity with rows of zeros after the decimal point. As

TABLE 2A
U.S. AIRPORTS DISTRIBUTION OF EXPENSES
1947

| | Percentage distribution of exp. | | Distribution of total exp. ($000) | |
|---|---|---|---|---|
| | | (1)[g] | | (2)[g] |
| Total expenses | | 100.0 | | 30,751 |
| 1. Salaries and wages | | 41.7 | | 12,823 |
| 2. Heat, light and water | | 6.5 | | 1,999 |
| 3. Insurance | | 3.8 | | 1,168 |
| 4. Telephone and telegraph | | .5 | | 154 |
| 5. Field maintenance | | 18.5 | | 5,686 |
| Labor | 6.0 | | 1,845 | |
| Other | 12.5 | | 3,844 | |
| 6. Building maintenance | | 1.3 | | 400 |
| Labor | .4 | | 123 | |
| Other | .9 | | 277 | |
| 7. Other | | 27.7 | | 8,518 |
| Supplies | 7.3 | | 2,245 | |
| Travel | 5.6 | | 1,722 | |
| Rent | 3.8 | | 1,168 | |
| Equipment maintenance | 2.5 | | 769 | |
| Taxes | 1.0 | | 308 | |
| Miscellaneous | 7.5 | | 2,306 | |

the table stands, all entries are related to the net air transportation services offered for sale, rather than to the gross operations of the air transport industry; to sell one million dollars' worth of air transportation the air transport industry must itself expend $23,800 (shown at sixth place on the table) and this amount, representing such things as test flying, ferry flying and other flying not for sale, must be added to every million dollars of service to give the gross operation in relation to the net.

The indirect inputs can be assessed from Table 4 by subtracting the figures in the "Direct Requirements" column from those in the "Total Requirements" column. In some industries a pronounced "feed back" effect exists, that is to say a large production of the industry may result from outside purchases of its product by the industry itself. For the air transport industry, the feed back is small, amounting to $47 per million dollars of service sold;[h] in the United States in 1955, on the basis of $1.6 billion of sales, the total feed back would be about $75,000.

TABLE 3
U.S. AIR TRANSPORTATION INDUSTRY TAXES AND MARKETING CHARGES
1947

Source: U.S. Department of Labor, Bureau of Labor Statistics.
(In Thousands of Dollars)

| | | |
|---|---|---|
| Summary of Taxes | | |
| A. Taxes—Total | | 50,975 |
| 1. Corporation | | 38,104 |
| (a) Federal | 22,324 | |
| (b) State & Local | 15,780 | |
| 2. Excise on Purchased Services | | 1,884 |
| (a) Federal | 1,855 | |
| (b) State & Local | 29 | |
| 3. Excise on Mat. Purchases | | 10,987 |
| (a) Transportation Tax | 169 | |
| (b) Other Federal | 6,396 | |
| (c) State & Local | 4,422 | |
| Summary of Marketing Charges | | |
| B. Marketing Charges—Total (on material purchases) | | 11,832 |
| 1. Retail Trade | | 4,399 |
| 2. Wholesale Trade | | 3,686 |
| 3. Railroad Transportation | | 1,926 |
| 4. Trucking | | 936 |
| 5. Other Water Transportation | | 772 |
| 6. Air Transportation | | 107 |
| 7. Warehousing & Storage | | 6 |

| Taxable or Chargeable Item | Producer's Values before Taxes & Marketing Charges | | Taxes & Marketing Charges | | Col. 3 ×100 ÷ Col. 2 |
|---|---|---|---|---|---|
| (1) | (2) | | (3) | | (4) |
| | $000 | | $000 | | % |
| Purchased Services including[i]; | | 155,157 | | 1,884[j] | 1.21 |
| Telephone | 8,908 | | 1,698 | | 19.06 |
| Telegraph | 1,027 | | 186 | | 18.11 |
| Material Purchases including[i]; | | 139,409 | | 22,819[k] | 16.37 |
| Fuel oils | 49,663 | | 20,642 | | 41.56 |
| Aircraft engines | 23,445 | | 659 | | 2.81 |
| Aircraft equipment | 15,715 | | 433 | | 2.76 |
| Tires & tubes | 2,508 | | 729 | | 29.07 |
| Mechanical measuring inst. | 3,992 | | 118 | | 2.96 |
| Printing & publishing | 1,709 | | 98 | | 5.73 |
| Manufacturing ice | 381 | | 20 | | 5.25 |
| Apparel | 69 | | 5 | | 7.25 |
| Greenhouse & nursery products | 56 | | 18 | | 32.14 |
| Bituminous coal | 44 | | 87 | | 197.73 |
| Anthracite coal | 12 | | 10 (see footnote l) | | 83.33 |

[g]The figures in Column (1) are based on a CAA Survey in 1946 of several airports. The figures in Column (2) have been obtained by applying the percentages from Column (1) to the total airport expenses, which were assumed to be equal to the total revenues.

[h]The $47 per million may be calculated by multiplying the gross operation, $1,023,800, by (1–direct requirements/$10^6$) i.e. by (1–0.023,201). This gives $1,000,047, the excess over $1,000,000 being "feed back" per million dollars of outside service.

[i]The other items shown under this heading in Table 2 are not subject to taxes and marketing charges.

[j]Excise taxes only.

[k]Marketing charges and excise taxes: $11,832,000 and $10,987,000 respectively.

[l]It is also of interest to note that Corporation Taxes ($38,104,000) amount to 4.81% of the total revenue of the air transport industry and, in 1955, Income Tax amounted to 5.16% of the total revenue.

TABLE 4

U.S. AIR TRANSPORTATION INDUSTRY DIRECT AND INDIRECT REQUIREMENTS FROM OTHER INDUSTRIES

1947

Source: U.S. Department of Labor, Bureau of Labor Statistics.

| Rank Order | Industry Sector No. | Industry Covering The Direct and Indirect Requirements of the Air Transport Industry | Air Transport Industry's Requirements At Producers' Values per Million Dollar Sale by the Former | |
|---|---|---|---|---|
| | | | Total Requirements Direct & Indirect | Direct Requirements |
| | | | $/Mill. $ | $/Mill. $ |
| (1) | (2) | (3) | (4) | (5) |
| 1 | 62 | Petroleum Products | 75,173 | 63,362 |
| 2 | 148 | Aircraft Industry | 57,162 | 50,697 |
| 3 | 17 | Crude Petroleum & Natural Gas | 40,100 | – |
| 4 | 181 | Banking, Finance & Insurance | 36,616 | 27,459 |
| 5 | 171 | Warehousing & Storage | 24,326 | 23,537 |
| 6 | 174 | Air Transportation | 23,800 | 23,201 |
| 7 | 183 | Real Estate & Rentals | 22,868 | 16,725 |
| 8 | 186 | Advertising, incl. Radio & Tele. | 20,737 | 17,114 |
| 9 | 47 | Printing & Publishing | 19,519 | 2,180 |
| 10 | 179 | Telephone & Telegraph | 14,973 | 12,675 |
| 11 | 180 | Eating & Drinking Places | 14,972 | 14,624 |
| 12 | 176 | Wholesale Trade | 11,668 | 6,072 |
| 13 | 169 | Railroads | 8,419 | 2,548 |
| 14 | 153 | Instruments, etc. | 7,979 | 6,068 |
| 15 | 167 | Electrical Light & Power | 7,292 | 2,345 |
| 16 | 188 | Auto. Repair Service & Garage | 7,205 | 5,959 |
| 17 | 177 | Retail Trade | 6,927 | 5,762 |
| 18 | 79 | Steel Works & Rolling Mills | 5,651 | – |
| 19 | 191 | Medical Dental & Other Pro. Services | 6,610 | 4,842 |
| 20 | 164 | Misc. Manufactured Products | 5,128 | 2,456 |
| 21 | 45 | Paper & Board Mills | 4,551 | – |
| 22 | 145 | Motor Vehicles | 4,147 | – |
| 23 | 189 | Other Repair Ser's (elect., watch, misc.) | 4,005 | 3,076 |
| 24 | 65 | Tires & Inner Tubes | 3,791 | 3,200 |
| 25 | 175 | Pipeline Transportation | 3,326 | 138 |
| 26 | 46 | Converted Paper Products | 3,183 | 366 |
| 27 | 173 | Other Water Transp. (non-overseas) | 2,936 | 1,067 |
| 28 | 16 | Coal Mining | 2,514 | 71 |
| 29 | 49 | Industrial Organic Chemicals | 2,467 | – |
| 30 | 170 | Trucking | 2,455 | 1,128 |
| 31 | 92 | Iron & Steel Forgings | 2,447 | – |
| 32 | 4 | Food Grains & Feed Crops | 2,115 | – |
| 33 | 168 | Natural Manu. & Mixed Gas | 2,088 | 168 |
| 34 | 26 | Misc. Food Products | 2,077 | 486 |
| 35 | 61 | Misc. Chemical Industries | 1,987 | 367 |
| 36 | 187 | Business Services | 1,970 | 799 |
| 37 | 30 | Spinning, Weaving & Dyeing | 1,704 | – |
| 38 | 44 | Pulp Mills | 1,688 | – |
| 39 | 56 | Paints & Allied Products | 1,634 | 735 |
| 40 | 21 | Meat Packing & Wholesale Poultry | 1,530 | – |
| 41 | 95 | Tools & General Hardware | 1,442 | 735 |
| 42 | 1 | Meat, Animals & Products | 1,401 | – |
| 43 | 28 | Alcoholic Beverages | 1,385 | – |
| 44 | 78 | Blast Furnaces | 1,348 | – |
| 45 | 89 | Aluminum Rolling & Drawing | 1,275 | – |
| 46 | 139 | Radio & Related Products | 1,271 | 367 |
| 47 | 55 | Soap & Related Products | 1,234 | 735 |
| 48 | 101 | Metal Stampings | 1,227 | – |
| 49 | 136 | Insulated Wire & Cables | 1,169 | – |
| 50 | 91 | Non-ferrous Foundries | 1,135 | – |
| 51 | 109 | Nuts, Bolts & Screw Machine Products | 1,128 | – |
| 52 | 66 | Misc. Rubber Products | 1,117 | 168 |
| 53 | 83 | Copper Rolling & Drawing | 1,112 | – |
| 54 | 82 | Primary Copper | 1,086 | – |
| 55 | 48 | Industrial Inorganic Chemicals | 1,074 | – |
| 56 | 51 | Synthetic Rubber | 1,037 | – |
| 57 | 59 | Vegetable Oils | 1,004 | – |

TABLE 4 (continued)

| Rank Order | Industry Sector No. | Industry Covering The Direct and Indirect Requirements of the Air Transport Industry | Air Transport Industry's Requirements At Producers' Values per Million Dollar Sale by the Former | |
|---|---|---|---|---|
| | | | Total Requirements Direct & Indirect | Direct Requirements |
| | | | $/Mill. $ | $/Mill. $ |
| (1) | (2) | (3) | (4) | (5) |
| 58 | 90 | Secondary Non-ferrous Metals | 971 | – |
| 59 | 126 | Valves & Fittings | 925 | – |
| 60 | 63 | Coke & Products | 851 | – |
| 61 | 22 | Processed Dairy Products | 860 | – |
| 62 | 60 | Animal Oils | 809 | – |
| 63 | 80 | Iron Foundries | 806 | – |
| 64 | 104 | Fabricated Wire Products | 772 | 367 |
| 65 | 36 | Logging | 755 | – |
| 66 | 117 | Cutting Tools, Jigs & Fixtures | 722 | – |
| 67 | 3 | Farm Dairy Products | 699 | – |
| 68 | 88 | Primary Aluminum | 688 | – |
| 69 | 27 | Sugar | 677 | – |
| 70 | 123 | Industrial Machinery n.e.c. | 673 | – |
| 71 | 131 | Motors & Generators | 673 | – |
| 72 | 24 | Grain Mill Products | 663 | – |
| 73 | 105 | Metal Barrels, Drums, etc. | 608 | – |
| 74 | 37 | Sawmills, Planning & Veneer Mills | 593 | – |
| 75 | 2 | Poultry & Eggs | 591 | – |
| 76 | 29 | Tobacco Manufactures | 575 | 367 |
| 77 | 127 | Ball & Roller Bearings | 557 | – |
| 78 | 163 | Motion Picture Production | 550 | 449 |
| 79 | 8 | Vegetables & Fruits | 539 | – |
| 80 | 9 | All Other Agricultural | 523 | 71 |
| 81 | 93 | Tin Cans & Other Tin Ware | 515 | – |
| 82 | 23 | Canning, Preserving & Freezing | 512 | – |
| 83 | 149 | Ships & Boats | 511 | – |
| 84 | 122 | Power Transmission Equipment | 509 | – |
| 85 | 7 | Oil Bearing Crops | 505 | – |
| 86 | 154 | Optical, Ophthalmic & Photo Equipment | 452 | – |
| 87 | 59 | Plastic Materials | 422 | – |
| 88 | 70 | Glass | 419 | – |
| 89 | 84 | Primary Lead | 410 | – |
| 90 | 102 | Metal Coating & Engraving | 408 | – |
| 91 | 185 | Other Personal Services | 408 | – |
| 92 | 75 | Abrasive Products | 397 | – |
| 93 | 128 | Machine Shops | 394 | – |
| 94 | 118 | Special Industrial Machinery | 393 | – |
| 95 | 94 | Cutlery | 392 | 367 |
| 96 | 125 | Refrigeration Equipment | 390 | – |
| 97 | 111 | Internal Combustion Engines | 390 | – |
| 98 | 5 | Cotton | 385 | – |
| 99 | 116 | Machine Tools & Metal Working Machinery | 383 | – |
| 100 | 178 | Local & Highway Transportation | 362 | 189 |
| 101 | 184 | Laundries & Dry Cleaning | 360 | – |
| 102 | 81 | Steel Foundries | 353 | – |
| 103 | 151 | Railroad Equipment | 349 | – |
| 104 | 155 | Medical & Dental Instruments & Supplies | 346 | – |
| 105 | 100 | Boiler Shop Products & Pipe Bending | 341 | – |
| 106 | 25 | Bakery Products | 339 | – |
| 107 | 54 | Drugs & Medicines | 333 | – |
| 108 | 12 | Copper Mining | 330 | – |
| 109 | 35 | House Furnishing & Other Non-Apparel | 324 | – |
| 110 | 40 | Wood Containers & Cooperage | 324 | – |
| 111 | 141 | Communication Equipment | 321 | – |
| 112 | 156 | Watches & Clocks | 302 | – |
| 113 | 160 | Office Supplies | 294 | – |
| 114 | 114 | Construction & Mining Machinery | 287 | – |
| 115 | 85 | Primary Zinc | 276 | – |

TABLE 4 (continued)

| Rank Order | Industry Sector No. | Industry Covering The Direct and Indirect Requirements of the Air Transport Industry | Air Transport Industry's Requirements At Producers' Values per Million Dollar Sale by the Former | |
|---|---|---|---|---|
| | | | Total Requirements Direct & Indirect | Direct Requirements |
| | | | $/Mill. $ | $/Mill. $ |
| (1) | (2) | (3) | (4) | (5) |
| 116 | 161 | Plastic Products | 273 | – |
| 117 | 119 | Pumps & Compressors | 271 | – |
| 118 | 137 | Engine & Electrical Equipment | 264 | – |
| 119 | 11 | Iron Ore Mining | 262 | – |
| 120 | 31 | Special Textile Products | 260 | – |
| 121 | 15 | Other Mining (Metals) | 257 | – |
| 122 | 133 | Electrical Control Apparatus | 257 | – |
| 123 | 42 | Metal Furniture | 250 | – |
| 124 | 129 | Wiring Devices & Graphite Products | 247 | – |
| 125 | 13 | Lead & Zinc Mining | 244 | – |
| 126 | 96 | Hardware n.e.c. | 235 | – |
| 127 | 99 | Structural Metal Products | 233 | – |
| 128 | 68 | Other Leather Products | 225 | – |
| 129 | 112 | Farm & Industrial Tractors | 211 | – |
| 130 | 41 | Wood Furniture | 197 | – |
| 131 | 124 | Commercial Machines & Equipment n.e.c. | 194 | – |
| 132 | 135 | Electrical Appliances | 187 | – |
| 133 | 86 | Primary Metals n.e.c. | 186 | – |
| 134 | 18 | Stone, Sand, Clay & Abrasives | 182 | – |
| 135 | 152 | Motorcycles & Bicycles | 179 | – |
| 136 | 6 | Tobacco | 174 | – |
| 137 | 67 | Leather Tanning & Finishing | 167 | – |
| 138 | 39 | Fabricated Wood Products | 165 | – |
| 139 | 52 | Synthetic Fiber | 165 | – |
| 140 | 140 | Tubes (Electronic) | 157 | – |
| 141 | 77 | Other Misc. Non-metallic Minerals | 153 | – |
| 142 | 43 | Partitions, Screens, Shades, etc. | 152 | – |
| 143 | 34 | Apparel | 147 | 88 |
| 144 | 76 | Asbestos Products | 146 | – |
| 145 | 10 | Fishing, Hunting & Trapping | 141 | – |
| 146 | 38 | Plywood | 138 | – |
| 147 | 20 | Other Non-metallic Minerals | 132 | – |
| 148 | 134 | Electrical Welding Apparatus | 128 | – |
| 149 | 57 | Gum & Wood Chemicals | 126 | – |
| 150 | 103 | Lighting Fixtures | 122 | – |
| 151 | 58 | Fertilizers | 121 | – |
| 152 | 53 | Explosives & Fire Works | 121 | – |
| 153 | 87 | Non-ferrous Metal Rolling n.e.c. | 114 | – |
| 154 | 115 | Oil-field Machinery & Tools | 109 | – |
| 155 | 115 | Jewelry & Silverware | 109 | – |
| 156 | 130 | Electrical Measuring Instruments | 106 | – |
| 157 | 142 | Storage Batteries | 101 | – |
| 158 | 132 | Transformers | 100 | – |
| 159 | 72 | Structural Clay Products | 99 | – |
| 160 | 150 | Locomotives | 96 | – |
| 161 | 98 | Heating Equipment | 96 | – |
| 162 | 138 | Electric Lamps | 89 | – |
| 163 | 71 | Cement | 87 | – |
| 164 | 32 | Jute, Linen, Cordage & Twine | 80 | – |
| 165 | 120 | Elevators & Conveyors | 78 | – |
| 166 | 73 | Pottery & Related Products | 74 | – |
| 167 | 19 | Sulphur | 70 | – |
| 168 | 74 | Concrete & Plaster Products | 62 | – |
| 169 | 64 | Paving & Roofing Materials | 60 | – |
| 170 | 146 | Truck Trailers | 59 | – |
| 171 | 113 | Farm Equipment | 56 | – |
| 172 | 106 | Tubes & Foils | 54 | – |
| 173 | 107 | Misc. Fabricated Metal Products | 53 | – |
| 174 | 159 | Toys & Sporting Goods | 52 | – |
| 175 | 108 | Steel Springs | 49 | – |
| 176 | 110 | Steam Engines & Turbines | 44 | – |
| 177 | 97 | Metal Plumbing & Vitreous Fixtures | 41 | – |
| 178 | 14 | Bauxite Mining | 30 | – |
| 179 | 121 | Blowers & Fans | 29 | – |
| 180 | 33 | Canvas Products | 25 | – |
| 181 | 69 | Footwear (excl. Rubber) | 19 | – |
| 182 | 172 | Overseas Transportation | 18 | – |
| 183 | 143 | Primary Batteries | 17 | – |
| 184 | 144 | X-ray Apparatus | 15 | – |
| 185 | 158 | Musical Instruments & Parts | 13 | – |
| 186 | 162 | Cork Products | 9 | – |
| 187 | 147 | Automobile Trailers | 4 | – |

Trucking and water transport (ranking in the 30th and 27th places respectively) are of interest. It will be noted that the direct trucking inputs ($1,128 per million) of the air transport industry in paying for goods which are priced at the producers' prices, i.e. excluding delivery charges, are actually less than the indirect inputs ($1,327 per million), that is the expenses incurred by other industries for their trucking services which must be allocated to other services for purchases by the air transport industry. Surprisingly, although the direct inputs of the air transport industry are less for inland water transport ($1,067 per million) than for trucking, the total inputs for the former ($2,936 per million) are greater than those for the latter ($2,455 per million), indicating that the indirect requirements for inland water transport are heavier than for trucking.

In many instances the total requirements are limited to indirect ones. Among these indirect inputs are names which sound strange in the air transport business, such as "locomotives" (entry No. 160), "farm equipment" (entry No. 171) and "musical instruments and parts" (entry No. 185). Like rare gases in our atmosphere, their names are strange because their contributions are less than 0.01%.

**The 1955 Requirements**

Table 5 presents an interesting comparison between Canadian and United States requirements for the calendar year 1955.

The higher unit prices paid by the Canadian carriers for most products, particularly for aviation fuel, are apparent. For cleaning compounds, however, something must have gone wrong with the definition of the term – perhaps they are taken in more diluted form in this country! The ratio of the prices of retreaded tires to the prices of new ones is higher in Canada than in the United States. This may be due to keener competition among Canadian suppliers of new tires than among their counterparts in the United States or to less exacting competition in the Canadian retreading industry; the

latter seems the more likely since evidently the United States trunk lines resort to retreading far more extensively than do the Canadian carriers. The ratio of retreaded to new tires used by United States trunk lines is 3.7:1 whereas the corresponding Canadian figure is little more than 2:1.

**REVENUES (OUTPUTS)**

In the U.S. input-output tables for 1947, it was decided for practical handling of the records to include in the consumers expenses (which constitute most of the "household" column) other elements such as travel and entertainment covered by expense accounts. For the railways, where about 85% of revenues are derived from carrying freight,[m] this practice had little effect on the main outputs. But for the air transport industry, the opposite is the case since about 85% of the revenues of U.S. air carriers stem from carrying passengers, most of whom are travelling on business. By distributing only the air freight revenues among the different industrial sectors and lumping all passenger fares under "household", the tables present a seriously distorted picture of the services rendered by the air transport industry.

The Survey of Current Business, published monthly by the U.S. Department of Commerce, contains tables showing Personal Consumption Expenditures by Type of Product on a yearly basis. Fortunately in the section on Transportation, the expenses for the inter-city air transport (domestic) are shown separately; for 1947 they amounted to $120,000,000. The passenger revenues of domestic scheduled airlines for that year, 1947, are quoted in the CAA Statistical Handbook of Civil Aviation of 1955 as $312,000,000 (including excess baggage). From these two figures it appears that the purchase of air service by private individuals amounted to only 38% of the whole. In 1954 practically the same proportion is maintained – $348,000,000 against a total of $916,000,000 (including $10.6 millions for excess baggage). Thus it would seem that 62% of the revenue from air passengers should be regarded as a service by the air transport industry to other industries rather than to the "household" sector, and that the revenue from private passengers – the true "household" item – is a relatively small portion of the whole.

Of course the picture may change with the introduction of the large jet airliners, scheduled for delivery in 1960. At that time the carriers' seating capacity may be far in excess of the present traffic forecast and to avoid flying these airliners half or two-thirds empty, it may be necessary to reduce the present fares considerably. This in turn may introduce the era of mass air transportation.[n]

[m]In 1955 the U.S. railways revenues from freight amounted to $8,538 millions of the total of $10,106 millions. (Transport Economics, I.C.C., issue of July 1956.) In the same year, passenger revenues of the U.S. certified air carriers accounted for $1,327 millions of the total of $1,598 millions.

[n]Today, even in the United States the portion of the total population not using air transport at least once a year is about 95%, taking into account the estimate that air passenger figures must be divided by 4.4 to account for flights made by the same persons.

TABLE 5

PROCUREMENT OF KEY MATERIALS BY THE CANADIAN AND U.S. AIR LINES 1955

Source: "American Aviation", issue of April 23, 1956.

| Item | Two Can. Air Lines | | United States Air Lines | | | |
|---|---|---|---|---|---|---|
| | | | Seven Major Trunk | | Local Service | |
| | No. Procured | Average Unit Cost | No. Procured | Average Unit Cost | No. Procured | Average Unit Cost |
| | | $ | | $ | | $ |
| Gas & Oil (1,000 gal).... | 59,659 | 0.26 | 844,817[o] | 0.178 | 38,098[p] | 0.182 |
| Spark Plugs........... | 51,938 | 2.42 | 655,000 | 1.65 | 7,450 | 1.65 |
| Tires (new)............ | 516 | 126.00 | 4,798 | 130.00 | 465 | 115.00 |
| Tires (retread).......... | 1,056 | 53.00 | 17,743 | 33.60 | 781 | 45.60 |
| Cleaning Compounds (gal).. ............ | 231,232 | 0.57 | 598,010[q] | 1.70 | 20,537 | 1.47 |
| Electronic Tubes....... | 16,509 | 2.80 | 143,007[r] | 2.77 | 10,971 | 2.40 |
| Electrical Wiring (1,000 ft)............ | 530 | 0.04 | 3,258 | 0.02 | 143 | 0.05 |

**CONCLUSION**

It need hardly be mentioned that this paper is put in general terms and barely begins to do justice to the pioneer work of Professor Leontief and his associates. The fact of the matter is that, popular impressions to the contrary, statistical study of economic aggregates is in its infancy.

**ACKNOWLEDGEMENT**

The author is grateful to Mr. H. C. Luttman for reading the draft of this paper and making numerous valuable suggestions.

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[o]All 13 domestic trunk lines.

[p]All 13 local service lines.

[q]Four carriers only.

[r]Three carriers only.

# C.A.I. LOG

## SECRETARY'S LETTER

**SPECIALIST SECTIONS**

An outline of the proposal to set up Specialist Sections is given on another page. This is a far-reaching development and one of considerable importance to the Institute.

When the Institute was originally formed, it was recognized that the technical people engaged in aviation in Canada were relatively few and that they must join forces to form a worthwhile organization. This is what we have done. But, though our numbers are few, our interests are no less diversified than those of people engaged in aviation in more populous countries and it is difficult to arrange for one organization to serve all these interests adequately.

The provision of Specialist Sections will enable members of like interests to get together to discuss their own particular problems; how much they do it is their own affair but at least the matter will be in their own hands and they will not have to wait their turns in Branch programmes or in the programmes of the main Institute meetings.

On the other hand, the Institute must continue to function as a unit. Although the specialists will now be able to retire into their respective corners, they must always remember that we are still all in the same room and that other people in the room, in other corners perhaps, can contribute to their discussions and should be invited to do so. This is the essential difference between a combination of Sections and an aggregate of independent societies; the Sections, each with its own objective, collaborate towards the common objective – in our case, the advancement of the art, science and engineering relating to aeronautics; whereas independent societies tend to overlap and, the more closely akin their individual objectives, the more the societies tread on each other's toes.

For a scheme like this to work, the parent body must itself be specialized – as we are in aeronautics – so that all its members will be at least fairly familiar with the work of the super-specialists. In such conditions, the super-specialists, though proudly exclusive in their respective Sections, will be aware that other members are interested in their problems and may be able to contribute useful ideas and suggestions.

Though many different terminologies have been used – chapters, branches, groups, sections and the rest – other organizations have applied the principle successfully and we believe that the introduction of Specialist Sections will enable the Institute to serve the many and varied technical branches of aviation, to their mutual advantage.

**TORONTO**

Although unfortunately I missed the Branch meeting by a couple of days, I visited Toronto on the 12th October on the occasion of the Official Acceptance of the first CS2F1 built by De Havilland. The opportunity was taken to visit Orenda Engines, where I discussed plans for the International Meeting with Mr. Keast, the Chairman of the Branch, and some of his committee members who are making the local arrangements. These discussions were very useful and the ceremony at Downsview was not only a significant event but enabled me to meet many members from far and wide – including, as an especially pleasant surprise, Mr. Cameron, Past Chairman of the Vancouver Branch. It was a day very well spent.

**A NEW MEETING**

I should like to draw attention to a new meeting, to be introduced this year into the Institute's programme, in addition to the International Meeting and the Annual General Meeting. This third meeting will be the first held outside the Montreal-Toronto-Ottawa triangle; it will be held in Winnipeg on the 25th and 26th February, 1957. This letter is not the place for details, but I mention the affair because it is an important step in the growth of the C.A.I. and, if it is a success and well attended, a major meeting outside the "triangle" will become a regular feature of our future plans.

**DISTINGUISHED VISITOR**

On the 10th October, we were honoured by a visit by Sir George Dowty, Honorary Fellow of the Institute and a Past President of the R.Ae.S. From our earliest days, Sir George has always shown a keen interest in the Institute and he presented our President's Badge to us. It was a great pleasure to welcome him to our Headquarters.

# INTERNATIONAL MEETING

## Programme

**November 26 Morning 9.00 a.m.**

**TEST FLYING**

Chairman
W. S. Longhurst
Chief of Flight Operations, Canadair Limited

*The Canadian Test Flying Scene*
Donald H. Rogers
Chief Test Pilot, Avro Aircraft Limited

*Flight Testing of High-Speed Aircraft*
Richard Johnson
Chief Engineering Test Pilot, Convair, San Diego
A Division of General Dynamics Corporation

*RCAF Test and Development*
S/L Owen B. Philp, RCAF
Formerly Chief Test Pilot,
Central Experimental and Proving Establishment

**November 26 Afternoon 2.30 p.m.**

**THE W. RUPERT TURNBULL LECTURE**

Chairman
J. C. Floyd
Vice-President, Engineering, Avro Aircraft Limited

*The Guided Missile as a Systems Engineering Problem*
Simon Ramo
Executive Vice-President, The Ramo-Wooldridge Corporation

**November 26 Evening**

**DINNER**

Chairman
T. E. Stephenson
President, Canadian Aeronautical Institute
Sales Engineering & Service Manager
Canadian Pratt & Whitney Aircraft Company Limited

Principal Speaker
C. C. Furnas
Assistant Secretary of Defense, Research and Development
*New Horizons – Military and Civilian*

**November 27 Morning 9.00 a.m.**

**QUALITY CONTROL**

Chairman
H. S. Rees
Chief Aeronautical Engineer, Department of Transport

*Quality Control Policy in the Royal Canadian Air Force*
G/C Robert McMillan
Chief of Quality Control, RCAF

*Applications of Ultrasonics in Aircraft*
Charles P. Albertson
Supervisor of Sonic Testing

Philip Melara
Supervisor, Quality Control Laboratory
Grumman Aircraft Engineering Corporation

*Control of Deviating Material*
Harold G. Dickie
Supervisor, Quality Review, Canadian Pratt & Whitney
Aircraft Company, Limited

**ELECTRONICS**

Chairman
G. F. Kelk
President, George Kelk Limited

*Operational Use of TACAN*
Murray Block
Air Traffic Control Specialist, Federal Telephone & Radio Co.,
Div. of International Telephone and Telegraph Corp.

*A Survey of the Advantages of Transistors in Air-Borne Electronic Equipment*
Earl F. Johnson
Head, Semiconductor Engineering Dept.,
Computing Devices of Canada, Limited

*Airport and Airways Surveillance Radar for Canadian Air Traffic Control*
Bruce McCaffrey
Project Engineer, Radar Dept., Raytheon Manufacturing Company

**November 27 Afternoon 2.00 p.m.**

**MISSILES**

Chairman
G. D. Watson
Director, Weapons Research, Defence Research Board

*Guidance and Control of Missiles*
A. G. Carlton
TRITON Division Supervisor, Applied Physics Laboratory,
The Johns Hopkins University

*The Technology of Guided Missiles and Its Effect on Industry*
R. D. Richmond
Chief Development Engineer

J. F. Perrier
Missiles Systems Engineer
Canadair Limited

*A Method for Evaluating Jet-Propulsion-System Components in Terms of Missile Performance*
R. J. Weber, Roger Luidens
Aeronautical Research Scientists, Lewis Flight Propulsion
Laboratory, NACA

# MEETINGS

**ANNUAL GENERAL MEETING**

NOTICES giving the full programme of the International Meeting have been sent to all members of the Institute; the programme is also set out on the opposite page.

**ABSTRACTS**

The following are abstracts of the papers to be presented at the International Meeting.

**The W. Rupert Turnbull Lecture**

*The Guided Missile as a Systems Engineering Problem*

S. Ramo – Ramo-Wooldridge Corp.

The advent of the guided missile system has widened the scope of engineering and applied physics required for a single engineering project. Not only does the guided missile system involve rapid and simultaneous advances on a number of technical fronts, but it has increased emphasis on an increasingly important but not new branch of engineering known as "systems engineering".

In this lecture, the nature of systems engineering applied to new and complex weapons systems is explored and illustrated using guided missile systems as examples. The problem of making quantitative, comparative analyses required in choosing from alternate missile systems will be discussed. Specific examples will illustrate the interaction and relationship of the numerous parameters stemming from various scientific disciplines that make up a complete guided missile system. Methods of analysis and the use of simulators and large-scale computers as tools will be described. The problem of prediction of performance of systems having nonlinearities and multiple parameters will be discussed at length.

It will be concluded that systems engineering of major guided missile systems is very difficult and, with the shortage of top technical talent, will become the limiting factor in the speed of technological advance in guided missiles and in similar complex new engineering development projects. Accordingly, the problem of improving systems engineering ability through discovery and best use of scientific talent especially suited and trained for systems engineering will be discussed.

*The Canadian Test Flying Scene*

D. H. Rogers – Avro

The number of pilots engaged in test flying in Canada has increased from a hardy half-dozen or so before World War 2 to between 60 and 70 at this time, including civilians in industry and service pilots in the RCAF and RCN. The various individuals and groups of test pilots have always felt an affinity of spirit but a remoteness of contact because of the geographic dispersion across our country from coast to coast.

This paper is intended to outline some of the background, growth and future of Canadian test flying, the available facilities, the types of work being undertaken and, finally, the formation of a Society of Canadian Test Pilots as a Section of the C.A.I. to provide a common ground for the exchange of information on flight test techniques, procedures and problems.

*Flight Testing of High Speed Aircraft*

by C. E. Myers – Convair
(replacing R. Johnson)

This paper serves to review a few of the methods which are being used to flight test high speed aircraft. The particular tests discussed are:

(1) Air Speed Calibration
(2) Longitudinal Stability
(3) Lateral-Directional Stability
(4) Roll Coupling
(5) Spin Recovery

The author states that the common concern among test pilots is escape at high speed. He reminds industry of its laggardness in producing an adequate high speed escape system.

*R.C.A.F. Test and Development*

S/L O. B. Philp – RCAF

This paper outlines the testing functions of Central Experimental and Proving Establishment, which is the unit responsible for Test and Development work in the RCAF. Brief accounts of the history, role, organization, flight test activities and the relation of this unit with the Canadian Aircraft Industry are given. The work of the RCAF Test Pilot, employed at the Central Experimental and Proving Establishment, is referred to throughout the paper.

*Quality Control Policy in the Royal Canadian Air Force*

G/C R. McMillan, R.C.A.F.

After frequent visits to the aeronautical industry throughout Canada the author has come to believe that RCAF Quality Control Policy is not well understood. The main purpose of the paper is to re-state and to explain that policy. The policy making organization is described and policy making is discussed. RCAF general policy is to achieve quality control by surveillance of approved firms rather than by RCAF inspection. The aim of this policy is to get the highest quality for the lowest cost. Subsidiary policies are also discussed; for example, management policy concerning duplication of inspection personnel and standardization policy involving interchangeability and test methods. The paper closes by making a plea that the aeronautical industry give the same precedence and importance to the quality control function as to any other manufacturing function.

*Applications of Ultrasonics in Aircraft*

C. P. Albertson, P. Melara – Grumman

The development of the ultrasonic tool has marked an important advance in the field of non-destructive testing during the past ten years. High frequency sound waves generated and detected by instruments currently in use have been successfully utilized to detect discontinuities in ferrous and non-ferrous materials. Ultrasonics has also provided the producer of metals with a method of measurement to aid in the improvement of the quality of aircraft constructional alloys. Ultrasonic inspection has given the designer added assurance of the quality of aircraft parts. The detection of injurious defects in material, prior to any large scale machining or fabricating operations, has prevented losses due to costly machining. The inspector now has another tool to evaluate the quality of material used in present day aircraft.

*Control of Deviating Material*

H. G. Dickie – Canadian Pratt & Whitney

This paper describes the methods and procedures used to effectively control and process deviating material under a modern Quality Control System. The procedure covers all aspects of manufacturing including raw material, purchased parts, in process deviations, final inspection assembly problems and embodies a workable corrective action system.

The procedure has been fully accepted by the RCAF as meeting all requirements of Q.C.S. – PROC 101.

*Operational Use of TACAN*

M. Block – Federal Telephone & Radio

A paper dealing with the advantages in aircraft operations and air traffic con-

trol that will be gained from the use of the RHO-THETA navigational aid, TACAN. The importance of navigational aids and communications in the development of the air traffic control system will be highlighted. The paper will be of an operational rather than technical nature. Although TACAN stands for tactical air navigation, common system application will be stressed.

*A Survey of the Advantages of Transistors in Air-Borne Electronic Equipment*

E. F. Johnson – Computing Devices

An examination of the electronics equipment carried by a typical airliner indicates that effective use of transistors will be possible in such aircraft. The examination consists of evaluating each separate vacuum tube application, then applying known savings factors for space, weight and power. The result indicates significant increases in economy, either through lower costs of aircraft construction or increased revenue earning capacity.

*Airport and Airways Surveillance Radar for Canadian Air Traffic Control*

B. McCaffrey – Raytheon

The unexpected increase in air traffic in North America has created serious hazards to human life. Unless positive steps are taken immediately to solve the underlying problems "Grand Canyon" disasters will become frequent. The Government of Canada has taken a long step in meeting its own Air Traffic Control requirements by ordering fifteen Airport and Airways Surveillance Radar systems for coast to coast installation.

The AASR has been designed to give maximum performance, reliability, ease of maintenance and long life. Performance of the equipment has been demonstrated by a radar equipment predecessor of which more than 1,000 units are in use throughout the world. Special features are included to satisfy the ATC operating requirements.

*Guidance and Control of Missiles*

A. G. Carlton–APL/Johns Hopkins

The guidance and control system of a guided missile comprises: Guidance Intelligence, to determine missile location relative to the target in a convenient reference system; Guidance Computing, which uses intelligence data to determine suitable missile maneuvres; and the Autopilot, which produces the maneuvers called for by controlling aerodynamic or other forces.

Significant interactions between guidance and aerodynamics, including aerodynamic performance requirements and impairment due to the guidance system design, and guidance accuracy reduction by aerodynamic and airframe characteristics, call for composite design taking guidance into account simultaneously with other factors or, in extreme cases, designing the missile in sequence, with guidance the initial consideration.

*The Technology of Guided Missiles and Its Effect on Industry*

R. D. Richmond, J. F. Perrier–Canadair

The physical laws involved and the principles of operation of guided missiles are considered. The development of a missile is treated as an extension of the construction of the aircraft, the singularly important change being the replacement of the pilot by an electronic computer; miniaturization, performance levels, expendability and environment are other significant changes. The effectiveness of the missile when integrated with other elements to form a complete weapons system is considered.

The problems to be solved by industry in manufacturing missiles and the continuing aspects of their development are treated. The technological level of Canadian industry is such that guided missiles should be produced efficiently in this country.

*A Method for Evaluating Jet-Propulsion-System Components in Terms of Missile Performance*

R. J. Weber, R. Luidens – NACA

Modification of a jet engine component often results in simultaneous changes in engine thrust, specific impulse, weight and external drag. Simplified mathematical expressions are developed to account for these effects on the range and the acceleration capability of airplanes or missiles. Several examples of the use of the method are presented, such as:

(a) Determination of the best expansion ratio of an exhaust nozzle as a function of its drag, weight and internal thrust.

(b) Evaluation of the relative importance of pressure recovery and external drag for supersonic inlets as a function of flight Mach number.

# MID-SEASON MEETING

## FORT GARRY HOTEL
## WINNIPEG

## 25th and 26th February 1957

| | | |
|---|---|---|
| **25th February** . . | Afternoon–2.00 p.m. to 5.00 p.m. . | Maintenance and Overhaul |
| | Evening–7.00 p.m. . . . . . . | Dinner |
| **26th February** . . | Morning–9.00 a.m. to 12.00 noon . . | Safety and Survival |
| | Afternoon . . . . . . . . . | Plant Tour |

The Principal Speaker at the Dinner will be

**MR. S. H. DEEKS**

***Executive Director***

***The Industrial Foundation on Education***

# SECTIONS

### SPECIALIST SERVICES COMMITTEE

Last May, with a view to improving the Institute's services to members specializing in various fields of aeronautical work, the Council set up a committee, known as the Specialist Services Committee, to study the subject and submit recommendations for consideration. This Committee comprised

G/C H. R. Foottit, Chairman
Mr. J. L. Orr
S/L O. B. Philp, and
Mr. R. J. Templin

### SPECIALIST SECTIONS

As a result of this Committee's work, the Council has now approved a scheme for the establishment of Sections. No Sections have yet been set up but the Council has defined their general framework and method of operation, to be applied to specific cases as they arise. Actually negotiations with a newly formed Canadian Test Pilots Society have been going on for some time and it seems likely that the Society will be reformed as the Test Piloting Section of the C.A.I. in the near future.

Broadly speaking a Section will be like a Branch but in a different dimension. A Branch is a geographical division of the Institute; the qualifications necessary to belong to a Branch are, firstly, to be a member of the Institute and, secondly, to live in the area served by the Branch. A Section will not be defined by geography at all; the qualifications necessary to belong to a Section will be, firstly, to be a member of the Institute and, secondly, to possess some qualification in the special field served by the Section. If the proposed Test Piloting Section comes into being, its members will be members of the Institute having certain qualifications – laid down by the Section and approved by the Council – associated with the art of test piloting; these members may be scattered right across Canada and they may belong, individually, to many Branches. Conversely a Branch may number among its members members of several Sections. It is not inconceivable that a member may even belong to two or more Sections, provided he has the necessary qualifications for each of them.

### FORMATION OF A SECTION

Each Section will be governed by its own Regulations administered by an Executive Committee. Normally, when the demand for a Section becomes apparent, the President will appoint a Committee, probably from among the moving spirits of the proposed Section, and this Committee will draft the Regulations and lay down the "identifying qualifications" necessary for membership. When these have been approved by the Council, a notice will appear in the Journal, announcing the approval of the formation of the Section and setting out the "identifying qualifications".

Members of the Institute who think that they possess the "identifying qualifications" and who wish to join the Section will then be required to submit applications, on special forms, which will be forwadred by the Secretary of the Institute, for consideration by the organizing Committee. Applications accepted by the Committee will be submitted for formal approval by the Council and the Secretary will notify the members concerned. (Members thus admitted to membership of a Section will not be required to pay any entrance fee or annual dues other than those normally payable for membership of the Institute.)

At an early date the members of the Section will elect their own Executive Committee, to replace the Committee originally appointed by the President, and thereafter elections of the Executive Committee will be held annually.

### FUNCTIONS OF A SECTION

It will be the duty of the Executive Committee of a Section to arrange programmes of activities specifically devised to help their members. It will be realized that the purpose of the Sections is to promote the technical development of specialist activities; in other words, the object of each Section, within its own field, must be consistent with the object of the Institute as set out in the By-laws.

Normally each Section will hold at least one meeting a year, which will constitute one of the Technical Sessions at the Institute's Annual General Meeting or at one of the other major meetings of the Institute. It may, of course, hold other meetings, if it can overcome the difficulties imposed by the fact that its membership may be widely scattered. Any group of members of a Section living within the area served by a Branch (they will also be members of the Branch) will form a "Group" within the Branch and may be called upon by the Branch to help with the Branch programme by arranging speakers, films and so forth, in their special subject.

Members of a Section will automatically receive copies of such bulletins, notices and leaflets as its Executive Committee may choose to distribute. Furthermore the Journal will contain news of the activities of all the Sections, Section notices and the like. Each Section, through its Executive Committee, will have some responsibility to all the members of the Institute in encouraging the submission of technical papers in its special field, to be considered by the Publications Committee for publication in the Journal.

It should be noted that, although membership of a Section requires special qualifications, the meetings of the Section are open to all members of the Institute, just as meetings of any Branch are open to members not living in the area served by the Branch. However, only members of the Section can vote in its elections–again, just as the right to vote in Branch elections is confined to members of the Branch.

### APPLICATIONS

Members of the Institute having specialist interests – aerodynamics, maintenance, inspection and quality control, structures, rocketry, etc. – who are interested in the formation of Sections, should first make some assessment of the possible scope of their respective specializations in Canada and gather a few kindred spirits, and then submit their cases for consideration by the Council.

# BRANCHES

**NEWS**

**Cold Lake**—Reported by R. W. Ellard

*September Meeting*

A business meeting of the Cold Lake Branch of the C.A.I. took place in the Airmen's Canteen on September 24, 1956, at 8 p.m. The meeting was opened by S/L R. G. Christie who gave a brief history of the Branch at Cold Lake followed by the announcement that the formation of the Branch had been officially approved by the Council.

S/L Christie then stated that either a new Executive Committee should be elected or the present Interim Executive should be confirmed in office until March, 1957. S/L B. D. McArthur proposed that the present Executive be confirmed in office. This motion was seconded by Mr. H. D. Proctor-Gregg. A ballot was carried out resulting in the Interim Executive Committee being confirmed in office.

A ballot for the election of Councillors was then carried out. Mr. D. L. Wallis was elected for a one year term and S/L B. D. McArthur was elected for a two year term.

F/S O'Neil suggested that a Membership Committee be formed consisting of one NCO, one Officer and one civilian. A ballot was taken to elect a Membership Committee and the following were elected: F/O J. S. Morris, Mr. J. R. Combley and WO G. A. Feltmate.

S/L Christie then requested that someone volunteer to become Chairman of the Programme Committee and W/C R. D. Ellis agreed to fill this role.

The meeting was concluded at 9.30 p.m. and refreshments were served. The meeting finally ended at 10.45 p.m. Twenty-five members were present.

**Winnipeg**—Reported by C. Gross

*September Meeting*

The first general meeting of the Winnipeg Branch of the 1956-57 season was held at the Westinghouse Auditorium on September 25, 1956, in the presence of 70 members and guests.

The Branch Chairman, Mr. J. J. Eden, welcomed all present and introduced the Chairman of the Programme Committee, Mr. B. W. Torell, the Chairman of the Membership Committee, F/L J. J. Deslauriers, the Chairman of the Social Committee, Mr. N. D. Brewer, and the Chairman of the Education and Training Committee, Prof. C. M. Hovey. A brief outline of the plans for the season was given.

The speaker, Mr. A. S. Jackson, Director of Traffic and Planning, Trans Air Limited, was then introduced.

Mr. Jackson's address was entitled "Vessels of the Air – A Case for the Flying Boats". He pointed out the advantages of flying boats with respect to landing and take-off, provided by their lack of dependence on runway restrictions. Their ability to force-land with little or no distress, particularly on the high seas, was stressed.

The basic fascination of things pertaining to the sea, the added feeling of safety and the improved visibility permitted by high set wings are reasons for increased passenger appeal provided by sea planes.

In contrast, some of the disadvantages of land planes were given as the great payload penalty caused by the necessity for heavy undercarriages on large aircraft, the increasing distances from town centres to airfields, the risk of accidents over metropolitan areas and the high cost of airport facilities.

The proposed plan for development of air service should include the establishment of flying boat fleets for long haul, land planes for feeder services to areas not naturally suited to flying boat operations and the development of supplemental aircraft, particularly of the rotary wing type.

Mr. Jackson concluded his talk with an outline of flying boat development and a description of the better known craft. The lecture was illustrated with slides.

Following a lively discussion period, Mr. A. R. Hunt expressed the appreciation of all present for this most stimulating talk.

**Vancouver**—Reported by I. A. Gray

*September Meeting*

Mr. P. Mussallem, Special Project Engineer, Imperial Oil Ltd., addressed the September meeting of the Vancouver Branch. His paper was entitled "Petroleum and Aviation Fuels".

Mr. Mussallem first took the group on a blackboard tour of specific portions of a petroleum refinery and patiently explained the intricacies connected with the distillation of the various petroleum products through the bubble tower and other 'cracking' apparatus. Having shown how the end products have been obtained, he then, in a very direct and understandable way, carried the audience through the intricacies of the basic carbon diagrams and showed how the changes within the diagrams produced various types of fuel, with particular reference to aviation fuel.

A simple explanation followed of the method of rating aviation fuels and the application of each of these products in airline and aircraft operation. Mr. Mussallem concluded his lecture by discussing the problems of obtaining jet fuels, ranging from the well-known straight kerosene type JP-1 to the more complex kerosene type JP-4.

In discussing the use of fuels in turbine engine operation, he touched upon the complex subject of flame chemistry and indicated where a possible improvement in combustion efficiency could be achieved by controlling the flame. It was most interesting to know that scientists do not understand the processes that occur within the flame of even a simple candle, let alone the more complex flame within the combustion chamber of either a piston or turbine engine.

*October Meeting*

On Saturday, October 13, at 8.00 a.m., forty members of the Vancouver Branch departed via Great Northern Railway for Seattle. Upon arrival at Seattle, the group was met by Mr. A. Hill, Director of Community Relations, Boeing Aircraft Co. Mr. Hill conducted the party to a special bus which took us to the No. 1 Plant at Boeing Field, where the members were treated to a most delicious lunch through the courtesy of the Boeing Aircraft Co.

After lunch, the party was taken to the auditorium where they were welcomed by Mr. R. Bateman, Vice-Chairman of the Seattle Section of the Institute of the Aeronautical Sciences. The group was then addressed by Mr. Maynard Pennell, Chief Engineer of the Transport Division, Boeing Aircraft Co. Mr. Pennell briefly described the organ-

ization of the Company, the products being designed and produced by the various divisions, and the part played by the Company in the National Defence Program, with specific mention of the B-52 bomber and the KC-135 tanker.

The group was then taken on a tour of the No. 1 Plant, beginning with the Engineering Dept., followed by the B-52 sub-assembly and final assembly lines. The subsonic, transonic and supersonic wind tunnels were then inspected in considerable detail. The Flight Development hangar was the next item on the tour and the test facilities for the structural testing of a complete aircraft of the size of the B-52 bomber were inspected with much interest. At the time, they were setting up to carry out a test on the KC-135 tanker. The group was then allowed to inspect externally the Boeing 707 transport in great detail. It was unfortunate that we were not permitted to go into the interior due to the test program in progress.

The party was then transported to the Renton Plant where they were allowed to inspect the sub-assembly and final assembly of the KC-135 tanker and the preliminary production facilities for the Boeing 707 transport.

The group was then returned to the Great Northern Station in downtown Seattle by way of Lake Washington, which is a lovely drive for an early fall evening through one of the most beautiful residential areas in Seattle.

The group arrived back in Vancouver at 10.20 p.m. after a most satisfactory trip.

**Montreal**—Reported by
W/C C. R. Thompson

*September Meeting*

The first meeting of the 1956-57 season for the Montreal Branch of the C.A.I. was a visit to the R.C.A.F. radar at Lac St. Denis. In spite of rainy weather and a long drive and the fact that the visit was confined to members only, over 65 members attended the talk and the tour of the station. The group were addressed by G/C R. W. McNair and were then shown around the radar site, including both the domestic accommodation and the technical operation.

The members, who are all engaged in one way or another in supporting aircraft operations, found the visit very interesting and most instructive. For obvious reasons more detail cannot be given in this report.

*October Meeting*

The first earth satellite launching, at 18,000 miles per hour at 320 miles above the earth, some time in 1958, part of the International Geophysical Year, was the subject of the talk by Mr. M. A. Winter to the Montreal Branch on the 17th October. Mr. Winter, the Manufacturing Manager of Project Vanguard at the Glenn L. Martin Aircraft Co., Baltimore, Md., was well qualified to speak on the subject.

Project Vanguard is a research programme for investigating outer space. Its scientific objectives include measurement of densities, temperatures, pressures, radiation of all wave lengths, including infra red to ultra violet and also including cosmic rays in the higher altitudes. It will also include the effect of mass distribution on the gravity field and it is expected that it will enable accurate geodetic determinations. The atmosphere of the earth is an effective filter, particularly for certain radiation wavelengths. The flights above the heavier part of this filter will enable radiation measurements which are impossible from the lower part of the atmosphere.

Up to the present, the total exposure of rockets at higher altitudes has been of the order of 10 hours. The satellite to be launched should allow the collecting of data over a much longer period, perhaps for up to a year.

The vehicle for carrying the satellite will be a 3-stage rocket varying from 45" to 32" in diameter and about 75' long, launched from Patrick A.F.B., Florida. The satellite itself will be a 20" sphere weighing about 21.5 lb. The satellite rockets will be fired in a southeasterly direction over the South Atlantic, south of South Africa and, due to the rotation of the earth, will not pass over the original launching point on each pass but rather will pass the same latitude at approximately 22.5° farther west on each pass. The latitude band covered by the successive orbits will be approximately 40° wide. The satellite is expected to circle the earth in 90 minutes or 16 times a day.

The first stage motor of the rocket will take the satellite 32 miles up and accelerate it to 3,200 mph. The second stage will take it to 139 miles up and 10,000 mph. Coasting flight of four minutes, with the altitude of the missile carefully controlled, will take it up to 300 miles with a slowing down to 9,200 mph. The missile will be spun on its axis by small rockets to stabilize its flight and rockets will separate the second stage motor from the third. The third stage motor will then accelerate the missile to 18,000 mph. The satellite will be separated by an explosion and it will then have been delivered as required by the contract.

The fuel for the first stage motor will be kerosene and liquid oxygen. The fuel will be pressurized by helium to deliver it to the pumps. The second stage motor will use nitric acid and an unsymmetrical di-methyl hydrazine. The third stage motor will be a solid propellant.

The fabrication of the rocket is similar to an aircraft type with skin, frame and stringers.

The tanks will be thin skinned aluminum spot welded structures. The outer skins will be made from semi-circular cylinders connected with a spot welded strap and a light fusion weld bead seal on the outside.

A complete testing programme of all components at all stages of assembly will be carried out. To do this many special tools will be required including the complete missile testing tool, which will be 92' high.

The completed missile will then be sent to Patrick A.F.B., where after further tests it will be fired.

At the end of Mr. Winter's formal talk, a film was shown of the Viking missile which illustrated, in beautiful technicolour, how the successor of the V2 and the forerunner of the Vanguard was fabricated, fueled and fired, with some remarkable movies from a rocket fired at up to 158 miles.

A lively question period followed which showed up Mr. Winter's humour and his adeptness in parrying questions. The questions elicited the information that the gross weight of the vehicle was 22,600 lb with a payload of 22.516. It was expected that the satellite would orbit for a year if it reached 300 miles up. If it should only reach 200 miles, then it would last only for weeks or months. If it should only reach 100 miles, it would last for hours. The battery for the transmitter is expected to last two weeks.

A question on organization brought the answer that 250 engineers were being used on the project but all the facilities of the large aircraft company were available for use as well as almost all other facilities in the U.S.A.

The speaker was introduced by the Branch Chairman, Mr. T. A. Harvie and was thanked by Mr. E. B. Schaefer. The attention paid by the 110 members and guests attending and the numerous questions afterwards showed that the talk held great interest to the Branch.

**Toronto**—Reported by W. T. Heaslip

*October Meeting*

A regular meeting of the Toronto Branch was held on October 10th in the De Havilland Cafeteria. The speaker, S/L R. D. Sloat, R.C.A.F. Chief Project Engineer of the Climatic Detachment at

Namao, was introduced by the Chairman, Mr. F. H. Keast.

In his introductory remarks, S/L Sloat pointed out that he would confine his talk to operation problems as indicated by the title of the address, "Cold Weather Operation of Aircraft", leaving out details of test procedures and detail aircraft analysis.

The establishment of design limits was the first point considered by the speaker in noting the difference between the American −54°C and the British −26°C specification temperatures. He presented graphs of temperature – altitude variations which indicated that a −40°C ground temperature and a −85°C temperature at 50,000 ft covered all but isolated conditions, and could therefore serve as a satisfactory basis for design.

In considering ground problems in cold weather, while noting that aircraft can be maintained at −40°C in the open, it was emphasized that shelter of some kind was most desirable. Simple shelters serving as windbreaks and permitting heating sufficient for gloves-off maintenance were illustrated. The problem of clearing snow and ice was approached noting that covers are suitable for small aircraft only, because of handling problems. Small covers are most essential to block off external openings, as snow etc., carried inside may melt and refreeze and jam critical components. S/L Sloat described a de-icing spray system for snow and ice removal from external surfaces, which while more expensive is quicker, more effective and safer than removal with flails and brooms. The dangers of melting off snow in a heated hangar without allowing time for complete drain-off and drying were pointed out.

Ground equipment also requires special consideration in cold temperature. Fuel must be kept cold to avoid freezing of water in warm fuel when put in cold aircraft tanks. Oil handling equipment, energizers and battery carts, on the other hand, must be kept warm to ensure satisfactory operation.

Starting of jet engines has presented no problems in cold weather and, in general, the same applies to turboprops, although trouble may be experienced with gear boxes unless suitable oils or heaters are provided. With reciprocating engines, oil dilution must be used to achieve sufficient cranking speed and some means must be used to achieve adequate fuel vapourization, i.e., heated fuel, high pressure priming, high volatile fuel for starting or heated intake ducts. Of these methods, heated intake ducts appears to be most reliable. General heating of the engine compartment with external source of heat is still the best solution to this starting problem. S/L Sloat highly recommended that the design of aircraft air heating or anti-icing systems provide the facilities for supplying this source of hot air. Hydromatic propellers provide viscous oil problems which can also be handled with dilution, which should be automatically operated on feathering to prevent in-the-air difficulties.

In-flight problems were introduced with the speaker pointing out that these are always present, irrespective of season or latitude, if sufficient height is reached. Cylinder head temperatures can be maintained with well designed cowl flaps which can also be used to give faster warm-up during cold weather ground starts. Oil cooler coring problems can be eliminated by avoiding coolers with thermostat bypasses and by operating with high oil temperatures. Oil breathers also require attention to prevent freezing up.

In concluding, S/L Sloat emphasized that the battery should be treated as a piece of emergency equipment and as such should not be used for ground duties during cold weather. To preserve its usefulness in flight, it must be in a heated compartment. The heat to this section should be sufficient during ground warm-up to ensure effective operation on takeoff.

In the question period following, the speaker noted that cold weather superiority of the nickel-cadmium battery had not been conclusively established. A discussion on undercarriage problems indicated that oleo seal design was the chief problem; tires contributed no difficulty if they were maintained at proper inflation pressure.

In answering questions on flying controls, S/L Sloat indicated that, while they required attention, they presented no serious problems although for high altitude, long duration flights spring compensators are probably required.

The speaker was thanked by Mr. R. T. Gibson of Avro Aircraft, who noted that the talk indicated that a need of awareness for the cold barrier was probably more real than for the heat barrier. He expressed the Branch's thanks for the effective way in which the need for care in detail design and in planning for cold weather operation had been described.

**Edmonton**—Reported by H. E. Davenport

*October Meeting*

The October meeting of the Edmonton Branch was addressed by Mr. K. F. Chapman, Project Engineer, Trans-Canada Air Lines, on the subject of Trans-Canada Air Lines' Viscount operation.

Mr. Chapman pointed out that in 1953 there were two aircraft available to replace the DC-3 – one an American twin engine and the other the Vickers Viscount. Very careful evaluation was necessary to determine which of these was the best suited for their operation and, after testing, the Viscount was chosen. It was shown that the delivery dates of new aircraft have introduced a serious problem, as types can become obsolete before delivery. T.C.A. now own over 30 Viscounts and the number will be increased during the next few years. Mr. Chapman went on to describe the aircraft with the aid of slides. Elements of wing structure were described and it was explained how analysis of wing loads under flight conditions has been carried out to determine safe life, a factor which is being very closely watched by T.C.A. The various aircraft systems were explained in good detail from structural, functional and maintenance viewpoints. The various automatic system functions were also discussed. Mr. Chapman next dealt with the Rolls-Royce Dart engine and the Rotol propellers, from both a structural and functional viewpoint. Various operational factors were then discussed, such as climb and cruise air speeds and engine speeds. No part of the aircraft was overlooked in this talk. A film, which dealt with the Viscount prototype, was shown after the conclusion of Mr. Chapman's talk.

S/L Sloat thanked Mr. Chapman at the end of his address.

**Ottawa**—Reported by S/L W. M. McLeish

*October Meeting*

The first technical meeting of the 1956-57 season was held in the N.A.E. Cafeteria Lounge at Uplands Airport. 148 members and guests attended.

Mr. M. S. Kuhring, Chairman of the Branch, opened the meeting and, since there was no business, called upon G/C W. P. Gouin to introduce the speaker, Mr. M. Winter, Manufacturing Manager of Project Vanguard at the Glenn L. Martin Aircraft Co., Baltimore, Md.

Mr. Winter divided his time between a film entitled "Horizon Unlimited" and a short description of Project Vanguard. The film was in itself more than enough to warrant the trip to Uplands. Its subject was the story of the development of the Viking upper atmosphere research rocket, which was designed and built for Naval Research by the Glenn L. Martin Co. The colours in the film were unusually good and rounded out the perfection of the planning, photography,

narrative and suspense, which the film achieved. The achievements of the Viking, a single stage vehicle, were presented in an unusually modest manner considering the degree of success of the missile and the superlatives which must have tempted the writer of the narrative.

By February 1955, 12 Vikings were released. Some failed to reach the upper atmosphere, but the majority captured upper atmosphere data concerning the ionosphere, atmospheric composition, temperature, pressure, density, cosmic and solar radiation, and photographic characteristics. The record for single stage rockets was claimed by Viking No. 11, 158.4 miles reached in 310 seconds, after accelerating to 4,380 mph at the time of powerplant shutdown. The powerplant on this flight operated 103.4 seconds with a maximum thrust of 21,400 lb from 11,985 lb of liquid propellant. The Glenn L. Martin Co. developed new manufacturing techniques to assist in the achievement of the goal of minimum weight and maximum performance, which was a major requirement in the Viking success. The ratio of airframe weight, 2,179 lb, to vehicle take-off weight, 15,005 lb, amply demonstrates this goal.

*(S/L McLeish's report on Mr. Winter's talk is similar to that reported by W/C Thompson on page 343 and will not be reproduced. — Sec.)*

A vigorous question period followed the lecture and film and Mr. Winter did a good job of handling the large audience. Finally after about 45 minutes of questions, Mr. Wood of N.A.E. was called upon to thank the speaker and we departed Uplands about 11 p.m.

# MEMBERS

## NEWS

**E. R. Fawcus, M.C.A.I.,** has left Canadair Ltd. to take up an appointment in the Sales Engineering and Service Dept. of Canadian Pratt & Whitney Aircraft Co., Ltd.

**F. L. Hartley, M.C.A.I.,** has been transferred from C.P.A.L.(Repairs), Calgary, where he was Superintendent of Maintenance, to the post of Assistant to the Director of Maintenance and Engineering, C.P.A.L., Vancouver.

**J. E. Laframboise, M.C.A.I.,** is now attending the Imperial College of Science and Technology, London, as a postgraduate student.

**K. E. Lewis, M.C.A.I.,** formerly with Canadair Ltd., has taken up an appointment as Design Engineer with Northrop Aircraft Inc., Hawthorne, Calif.

**W. B. J. Shakespeare, M.C.A.I.,** has terminated his employment with Canadair Ltd. and is now employed at Northrop Aircraft Inc., Hawthorne, Calif.

## ADMISSIONS

At a meeting of the Executive Committee of the Council, held on the 1st October, 1956, the following were admitted to the grades of membership shown.

***Associate Fellow***

**A. H. C. Greenwood,** Assistant General Manager, Vickers-Armstrongs (Aircraft) Ltd., Weybridge, Surrey, England.

**G. F. Kelk,** President, George Kelk Ltd., 130 Willowdale Ave., Willowdale, Ont.

***Member***

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**H. E. Davenport** (on transfer from Technical Member).

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## APPOINTMENT NOTICES

*The facilities of the Journal are offered free of charge to members of the Institute wishing to give notice of positions vacant or required. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.*

*The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.*

*Box 100* **Aeronautical Engineer** B.Ae.E. Thirteen years experience, covering design, flight test and analysis of aircraft and helicopters, industrial engineering, sales engineering, with four leading Canadian manufacturers and airlines, desires improved opportunities as Technical Assistant to Management, Technical Sales Representative or Planning and Economic Analysis.

*Box 101* **Aeronautical Engineer** Twelve years experience in research, design, flight testing of aircraft, missiles and power plants, systems engineering, seeks position with industry or airline. Ample experience in contract and project administration on staff level and liaison engineering.

# SUSTAINING MEMBERS

## NEWS

**Data Processing Associates Ltd.** announce that, as a result of their merging with ElectroData and Burroughs Adding Machine, they have changed the name of the Company to the ElectroData Division of Burroughs Adding Machine of Canada Ltd.

**Northwest Industries Ltd.** report that work has begun on the construction of a new Instrument and Electronics Laboratory Building to replace the old building which was destroyed by fire last May. The new building will have a floor area of 19,300 sq ft – the old building covered 15,000 sq ft – and is expected to be completed and ready for use by late February.

**Orenda Engines Ltd.** has now started the first of its courses of lectures designed to prepare employees for the examinations of the Association of Professional Engineers of Ontario; the examinations will be held in March. A group of 30 has been selected to take the first course which will be conducted by qualified engineers employed by the Company and will comprise 2½ hours of lectures given three afternoons a week.

Orenda Engines Ltd. also announce good progress in their expansion programme which was announced last April.

At Nobel, the engine and afterburner combustion test cell is completed and in operation. In the same building, the rotating cooled blade test cell construction is completed and test equipment is being installed. The facility will be in operation early next year. The new office and stores building is erected and transfer of operations from the older building will begin early in November and be completed by the end of the month.

At Malton, construction of two of the six new development test cells and their central service building are scheduled to be finished by the end of this year and in operation about two months later. The remaining four cells are scheduled for completion in April of next year and for operation about two months after that date. In each case the two-month interval will be occupied with the installation of various measurement devices necessary for engine testing.

Construction of the high altitude test facility is scheduled for completion next May and should be ready for operation in September. The September date coincides with Ontario Hydro's schedule for supplying electric power from its new Richview sub-station.

Some 20,000 hp will be needed for the electric motors which will drive the Orenda - designed and manufactured compressors and other equipment required for test operations and located in the high altitude test building. Altitudes up to about 70,000 ft and temperatures down to about –70° will be simulated for engine testing and this controlled temperature and pressure will be piped to the high altitude test facility where engine running and fuel combustion under these extreme conditions will be studied.

**Computing Devices of Canada Ltd.** has concluded an agreement with Bendix Aviation Corporation through its Canadian subsidiary, Bendix-Eclipse of Canada Ltd., whereby Bendix has acquired a 40% interest in C.D.C. and a sales and licensing arrangement has been established in which C.D.C. will handle a large group of Bendix products in the electronic and missile component areas. A close working arrangement is already under development between C.D.C. and the 24 divisions of Bendix for a continuous exchange of engineering developments and progress.

Bendix products to be handled in Canada by C.D.C. include missile components of all kinds, telemetering, radio communication and navigation equipment, radar and several new Bendix industrial electronics products such as Lumicon, industrial control and telemetering systems, nuclear and meteorological equipment.

**Aviation Electric Ltd.,** who have long been the representatives for Bendix in Canada, have now established an exclusive sales and licensing arrangement with Bendix in the fields of aviation fuel devices of all kinds; ignition equipment; landing gears, struts, wheels and brakes; electrical equipment for aviation; navigation, flight and engine control instruments of all kinds; automatic pilots and flight control equipment.

## AMENDMENT OF THE BY-LAWS

The various amendments to the By-laws which were voted upon by the membership of the Institute last March have now been approved by the Secretary of State and have, therefore, become effective.

The By-laws and Regulations, embodying these amendments, are now being printed and will shortly be available for distribution. Copies may be obtained, on request, from C.A.I. Headquarters or from Branch Secretaries.

# BOOKS

**Supersonic Inlet Diffusers and Introduction to Internal Aerodynamics.** By R. HERMANN. Aeronautical Div., Minneapolis-Honeywell Regulator Co., Ltd. 378 pages. Illus. $16.00.

This book treats supersonic diffusers with particular emphasis on inviscid internal flow through supersonic inlets. The contents, based on graduate courses at the University of Minnesota, include the following.

Ch 1. Function and application of supersonic diffusers; steady flow energy equation.

Ch 2. One-dimensional inviscid analysis for normal shock wave ahead of diffuser: performance with sonic throat; starting processes.

Ch 3. One-dimensional inviscid analysis for normal shock swallowed: performance at and above design Mach number; subsonic diffuser efficiency.

Ch 4. Two-dimensional inviscid analysis of symmetric multiple shock diffuser in a duct.

Ch 5. Introduction to two-dimensional multiple shock inlets.

Ch 6. Oswatitsch analysis of two-dimensional multiple shock systems giving maximum pressure recovery.

Ch 7. Application of Oswatitsch analysis to practical two-dimensional inlets: comparative performance of various configurations.

Ch 8. Three-dimensional spike inlet at design Mach number: two shock inlet with unchoked exit nozzle; regimes of operation with choked exit nozzle.

Ch 9. Experimental wind tunnel data for spike inlet performance: stationary flow results at and below design Mach number; wind tunnel results and present theories of nonstationary (buzz) phenomena.

Considerable emphasis is placed on the author's personal contributions in the field and frequent use is made of research results obtained under his supervision at the Rosemount Aeronautical Laboratories, University of Minnesota. There is frequent comparison of theory and experiment and abundant graphical presentation of analytic results. The text is very well illustrated.

The engineer faced with the problems of supersonic inlet design will likely find the omission of the external aerodynamics and inlet drag a serious shortcoming.

J. G. HALL

**Stresses in Aircraft and Shell Structures.** By PAUL KUHN. McGraw-Hill Company of Canada Ltd., 1956. 435 pages. Illus. $16.80.

The author states that with this book his aim was to go "a step beyond My/I and T/2A". This he does admirably by the use of simplifying procedures which reduce complicated structures to simple "substitute" ones. The analysis of the simple structures provides a clear picture of the way they work. The book thus has a collection of modules which can be the building blocks of design. Kuhn notes where these simplifications fail and points out that different simplifications may be required of the same structure for different loadings. He notes that though "classical" analysis of the unsimplified structure is gaining impetus under the influence of modern high speed computing machines and may become the final analysis in the substantiation of a structure, there will always remain the need for "Design" analysis where the designer "roughs out" the stress patterns of several alternate designs in an effort to select the optimum.

Pains are taken to differentiate between the finding of stresses in a loaded structure and the assessment of whether the structure will withstand them. The book is devoted to the first question and, with one exception, the reader is directed to other references for the answers to the second. The exception is that strength data is given for tension-field beams.

From the elementary theories of beam action the book proceeds to tension-field beams, shear lag or stress diffusion and its modifying effect on the elementary beam theory stresses. The stress distribution due to the restraint of warping in a four flanged shell under torsion follows naturally from here and is extended in the next chapter to multi-stringer construction. Cut-outs in plane panels and box beams are dealt with next followed by a chapter on cut-outs in circular cylinders.

Experimental evidence to substantiate the methods presented fills the remainder of the book. Each of the topics is treated in turn using the results of approximately 15 years of structural research, largely those of the N.A.C.A. The reader is shown the degree of agreement with experiment and is enabled to get a feeling for the applicability of the methods.

The presentation of these procedures and their validating test data collocates many original references of American, British and German origin which may not be readily available to the Student or, if they are, present no logical pattern. Here they are arranged so that they present a unified treatment of the problems in a form suitable as a text book. Its printing is excellent; its illustrations models of clarity; but the price is high. This reviewer would like to see a more economical second printing which would help to give it the wide use that it deserves.

J. P. UFFEN

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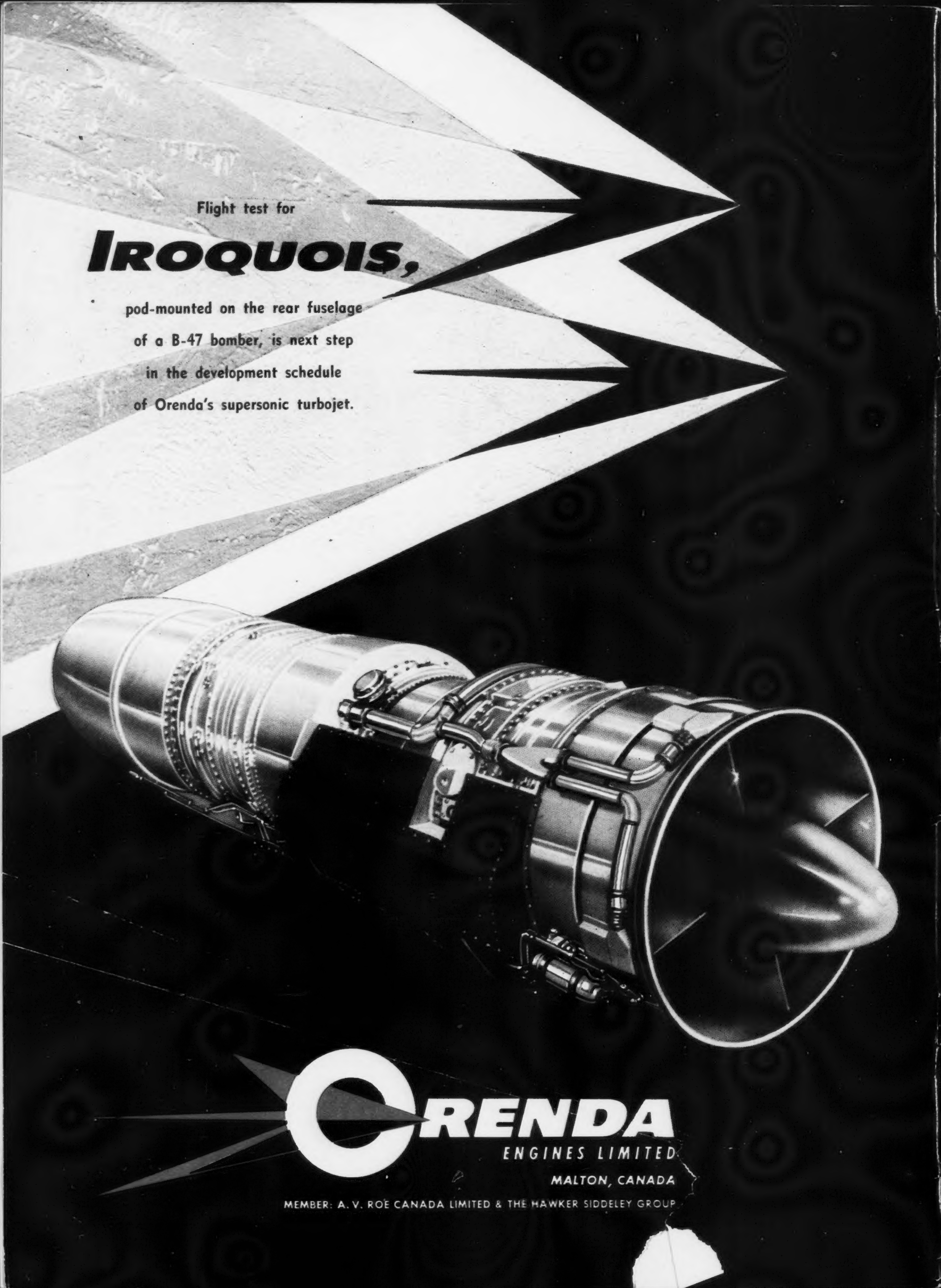
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